COST ANALYSIS

Washington Department of Ecology Year 2001 Minimum Requirements for Stormwater Management in Western Washington

Washington State Department of Transportation

August 2001

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Washington Department of Ecology Year 2001 Minimum Requirements for Stormwater Management 2001

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Table of Contents

Tables

Figures

Preface

This document contains information on the cost of implementing the new minimum stormwater control requirements for new developments and redevelopments as set forth by the Washington Department of Ecology (Ecology) in its *Stormwater Management Manual for Western Washington* (Ecology 2001). The minimum requirements include provisions for controlling erosion and sediment transport during construction, as well as permanent facilities for treating and controlling peak runoff flows from developed sites. This cost analysis considers only the stormwater system components required for erosion and sediment control, stormwater treatment, and stormwater detention and/or infiltration that go beyond conventional stormwater systems. Thus, the costs of installing stormwater system components such as catch basins and conveyance pipes that are independent of the Ecology requirements are not addressed in this cost analysis.

The cost estimates for satisfying Ecology's new minimum requirements that are provided in this report should be considered as approximate, and should be viewed in the context of the hypothetical sites for which they were developed. Individual site conditions, selected components of stormwater control plans, costs of land, costs of engineering and construction services, and many other factors can vary considerably throughout western Washington and from project to project. Some projects will be faced with costs associated with construction of stormwater management facilities that are not captured in this analysis, such as traffic control costs, additional property costs, and mitigation costs for sensitive areas that are impacted by placement of stormwater management facilities. Therefore, for a particular development or redevelopment of comparable size to the hypothetical sites discussed in this report, the costs of satisfying Ecology's minimum requirements may differ from the costs given in this analysis. This analysis does not address the costs that stormwater design engineers, site designers, developers, and development reviewers may incur in learning the updated requirements and preparing the resultant technical documentation that will likely require greater detail.

1. Introduction

This report provides information on costs of stormwater control measures required for new single-family residential and commercial developments in western Washington based on the minimum requirements set forth by the Washington Department of Ecology (Ecology) in the *Stormwater Management Manual for Western Washington*, referred to hereafter as "the manual" (Ecology 2001, final version pending as of the date this report was completed). The manual describes the stormwater management requirements applicable to various development and redevelopment scenarios, including many types of development other than single-family residential and commercial land use. There are a multitude of development scenarios that could potentially be evaluated for stormwater management implementation costs but doing so would require extensive amounts of time and effort. This report discusses the range of stormwater management costs that could be expected for some representative examples, and the reader must necessarily use the information as a general guide to understand the cost implications for a specific project of interest.

Development Examples

This report addresses three hypothetical development examples and presents the associated costs for compliance with Ecology's new minimum requirements. These three hypothetical development sites include the following: a 10-acre single-family residential development (site 1), a 1-acre commercial development (site 2), and a 10-acre commercial development (site 3). These examples assume that new development is occurring on the hypothetical sites, that there is no existing development on the sites, that greater than 2,000 square feet of impervious surface is added, and that greater than 7,000 square feet of land area is cleared. Therefore, all of the minimum requirements set forth in the manual are applicable to these examples. Because the decisions regarding how to manage stormwater for a particular site are often directly tied to soil characteristics, this report addresses a range of control measures that may be used in differing soil conditions. For each of the three example sites, the costs to implement the minimum requirements were analyzed for two different soil conditions (soils that would promote infiltration of runoff [type A soils] and soils that are not suitable for infiltration [type C soils]).

This report may be viewed as an update to a similar report prepared in 1993 entitled *Cost Analysis, Minimum Requirements for Stormwater Management in New Developments and Redevelopments* (Herrera 1993), which contained an analysis based on requirements set forth in the *Stormwater Management Manual for the Puget Sound Basin* (Ecology 1992). The analysis in this report repeats the hypothetical development examples from the 1993 report, and the analysis is based on the minimum requirements, design guidelines, and stormwater facility sizing procedures in the updated 2001 Ecology manual. Where applicable, this report refers to the 1993 cost analysis report to enable comparison of the differences in stormwater management costs between the older and newer requirements for the same site conditions.

Soil type is an important difference between the 1993 report and this report. The 1993 report used type B soils for the examples where infiltration was assumed feasible, whereas the present analysis assumed type A soils (i.e., glacial outwash or alluvial deposits that are more permeable than type B soils) for the examples where infiltration is assumed feasible. This distinction is important because it affects the selection and configuration of the permanent stormwater facilities. Specifically, the 1993 report assumed infiltration treatment would occur in type B soils, with overflow to a detention facility in higher storms. This analysis assumes pretreatment followed by flow disposal in the highly permeable type A soils. The decision to switch to Type A soils was based on the type of soil input data that the pending Ecology hydrologic model will allow, and a desire to have the case study examples match the model input options as directly as possible. To enable a fair cost comparison of 1992 requirements versus 2001 requirements for the examples where infiltration is feasible, the soil type must be consistent. Therefore, the permanent stormwater management system quantities and costs associated with type B soils in the 1993 report were disregarded, and new costs were developed for those examples assuming type A soils. As discussed in Appendix C of this report, quantities and costs were re-analyzed for the three sites assuming pretreatment and discharge of all runoff to an infiltration basin, using the 1992 design requirements to derive the sizes of those facilities. Thus, the comparison of permanent stormwater management costs associated with the previous requirements and the new requirements, presented at the end of this report, is based on updates to the 1993 cost figures for the non-infiltration examples and new cost figures for the infiltration examples.

Ecology's Minimum Requirements

Ecology's stormwater management requirements have changed substantially since 1992. In order to demonstrate compliance with Ecology's minimum requirements, preparation of a construction stormwater pollution prevention plan (SWPPP) and a permanent stormwater site plan is required for all new development sites that will create more than 2,000 square feet of impervious surface or clear more than 7,000 square feet of land area. The updated minimum requirements, which are discussed in detail in the manual (Ecology 2001), are summarized below with the changes highlighted:

1. **Preparation of Stormwater Site Plans –** All projects shall prepare a stormwater site plan for local government review.

   Significant Change: Demonstration of compliance with the 1992 manual required preparation of a Stormwater Site Plan. However, such plan preparation was not specifically identified as a minimum requirement. The updated manual specifically identifies the preparation of such plans as a minimum requirement. This is not a change that increases project costs.

2. **Construction Stormwater Pollution Prevention (SWPP) –** All new development and redevelopment shall comply with the 12 construction SWPP elements found in the manual.

Significant Changes: A new element to "Manage the Project" has been added. This includes phasing of construction activities, seasonal work limitations, coordination with utilities, inspection and monitoring of BMPs, retention of a certified professional in erosion and sediment control, and maintenance of a Stormwater Pollution Prevention Plan (SWPPP). Significant BMP additions that need to be considered in SWPPPs include chemical treatment, land application of polyacrylimide for soil stabilization, wheel washing, concrete handling, and sawcutting and surfacing.

3. **Source control of pollution –** All known, available and reasonable source control best management practices (BMPs) shall be applied to all projects.

   Significant Changes: There are 18 new source control BMPs described in the 2001 manual.

4. **Preservation of natural drainage systems and outfalls –** Natural drainage patterns shall be maintained, and discharges from the site shall occur at the natural location, to the maximum extent practicable.

5. **Onsite stormwater management –** Projects shall employ onsite stormwater BMPs to infiltrate, disperse, and retain stormwater runoff onsite to the maximum extent practicable without causing flooding or erosion impacts.

   Significant Change: This new requirement specifies use of flow dispersion or infiltration BMPs for concentrated runoff from impervious surfaces at residential sites, and for all areas not covered by impervious surfaces, the retention or enhancement of the soil moisture holding capacity of the original undisturbed soil native to the site. Specifically, the requirements include provision of a topsoil layer with a minimum organic matter content of ten percent dry weight and a pH from 6.0 to 8.0 or matching the pH of the original undisturbed soil.

6. **Runoff treatment –** Projects that meet specific thresholds are required to construct stormwater treatment facilities that are sized to treat runoff from the water quality design storm (the 24-hour rainfall amount with a 6-month return frequency).

   Significant Changes: Treatment is required for pollution-generating pervious surfaces (PGPS), such as managed turfgrass, in addition to pollution-generating impervious surfaces (PGIS). The Water Quality Design Storm Event is still a 6-month, 24-hour storm, but the generic estimate for precipitation depth in such a storm event is increased from 64% to 72% of the 2-year, 24-hour storm precipitation depth.

7. **Flow control –** Projects that meet specific thresholds must provide flow control to reduce the impacts of increased stormwater runoff from new impervious surfaces and land cover conversions.

   Significant Changes: A flow duration standard is now the default requirement. The flow control standard in the 1992 manual was primarily targeted at matching pre-developed peak flow rates. The newer standard still requires matching of pre-developed peak flow rates but also requires matching of pre-developed flow durations to prevent prolonged discharges of the peak flows. In addition, the pre-developed site condition for runoff modeling purposes must be assumed forested unless reliable information establishes the pre-settlement conditions as pasture or prairie. The 1992 manual allowed use of the "existing site condition," as defined in the glossary, as the pre-developed condition to which peak flows of the developed condition are compared.

8. **Wetlands protection –** Discharges to wetlands shall maintain the hydrologic conditions, hydrophytic vegetation, and substrate characteristics necessary to support existing and designated uses unless an assessment is completed consistent with specific criteria referenced in the manual.

9. **Basin/watershed planning –** Projects may be subject to equivalent or more stringent minimum requirements for erosion control, source control, treatment, wetlands protection, and operation and maintenance, and alternative requirements for flow control as identified in basin/watershed plans.

10. **Operation and maintenance –** An operation and maintenance manual that is consistent with the local government standards shall be provided for all proposed stormwater facilities and BMPs, and the party (or parties) responsible for maintenance and operation shall be identified.

The Stormwater Pollution Prevention Plan

The SWPPP must incorporate sufficient best management practices (BMPs) to prevent adverse offsite impacts during construction through a variety of measures as specified in minimum requirement number two. Twelve distinct elements of effective construction site pollution prevention must be included in the SWPPP to the extent they pertain to the site.

The Permanent Stormwater Site Plan

The permanent stormwater site plan must include the following elements to comply with the minimum requirements:

- Minimum requirement three: additional BMPs for prevention of runoff pollution, or source control

- Minimum requirement five: This important new requirement relates to implementation of onsite stormwater management measures to minimize the hydrologic changes that occur on the site (i.e., to minimize the increase in runoff that is inherent with development). The cost analyses discussed in this report incorporate this requirement. The effects of new onsite runoff reduction measures on the size and cost of permanent runoff treatment and flow control facilities are discussed for each development example.

- Minimum requirement six: treatment of onsite runoff to protect downstream water quality

- Minimum requirement seven: control of peak runoff flows that may otherwise cause damage to natural resources and constructed facilities downstream

- Minimum requirement ten: long-term operation and maintenance commitments for permanent stormwater management systems

Thoughtful selection and proper implementation of BMPs are critical to satisfying Ecology's minimum requirements for stormwater management for new development or redevelopment. In this analysis, the rationale for selection of particular BMPs is provided for each of the hypothetical development plans to illustrate the process by which BMPs were chosen.

Organization of the Cost Analysis

The remaining portion of section 1 outlines the assumptions used in creating hypothetical development site layouts. Also discussed are the assumptions and calculation methods used in analyzing minimum requirements for stormwater control and for sizing and selecting stormwater management BMPs.

Section 2 describes the hypothetical site characteristics and associated SWPPP and stormwater site plan details developed for the purpose of estimating costs to satisfy the minimum requirements. The estimated costs for planning, designing, constructing, and maintaining the chosen BMPs for each site are also provided in Section 2. Section 3 presents a summary of the construction and maintenance cost estimates for satisfaction of the minimum requirements, and discusses comparisons to the costs presented in the 1993 report associated with the previous minimum requirements. Appendix A contains itemized costs for planning, design, construction, and maintenance of the BMPs for each of the development sites, as well as assumptions and references used in developing the cost estimates. The technical assumptions, runoff modeling

parameters, and design parameters used in the analysis of stormwater BMPs for each of the sites are outlined in Appendix B.

The SWPPP and stormwater site plan developed for each of the hypothetical sites are intended to be representative in their coverage of BMP concerns, but they do not include all of the information required of actual SWPPPs and stormwater site plans. Because this analysis focuses primarily on costs, details regarding site features such as setback requirements, existing vegetation to be retained, rights-of-way, and storm sewers, among other issues, are limited.

General Assumptions Used in Creating Hypothetical Site Layouts, Analyzing Minimum Requirements, and Selecting and Sizing Stormwater Management Facilities

The hypothetical development site layouts and associated stormwater facilities are based upon the assumptions outlined below:

- Each site is serviced by separate sanitary sewer and storm drainage systems. The cost of installing ditches or storm sewers beyond the site boundaries is a separate concern; this analysis addresses only the additional storm drainage facilities needed for treatment, infiltration and/or detention of runoff on the example site.

- Ground slopes on all of the sites are less than 5 percent.

- The land uses adjacent to the sites on all sides are unknown.

- Stormwater runoff on all of the sites eventually drains to a fish-bearing stream. For the commercial site examples (sites 2 and 3) this means that "enhanced treatment" of runoff is required.

- Phosphorus control is not required at any of the sites.

- Other more stringent local stormwater management requirements do not apply, and a jurisdictional basin plan does not exist for any of the site areas.

Costs for complying with the minimum requirements at each of the development sites are based on two scenarios: the first scenario assumes the site has outwash soils that are suitable for infiltration of all, or nearly all, of the stormwater runoff; the second scenario assumes till soils that are unsuitable for infiltration. Two separate cost estimates are provided for implementation of the minimum stormwater management requirements at each site, reflecting the two types of soils assumed at each site. Other than differences in the soil type present, the site characteristics are identical for the two scenarios evaluated at each site.

Calculation Methods

A combination of hydrologic modeling methods was used to perform conceptual sizing of stormwater management facilities for this analysis, including some modeling methods that are not described in the manual. The hydrologic model that eventually will be used for analysis and design of stormwater management systems in accordance with the manual's design criteria was in the developmental stage at the time this report was prepared; therefore, alternative methods were necessary. The 6-month recurrence interval water quality design storm hydrographs for the case study development examples were derived using StormShed™ computer software (Engenious Systems 2000), which incorporates the Santa Barbara Urban Hydrograph (SBUH) method. The model inputs are summarized in Appendix B. The performance of detention systems, including matching of pre-developed flow durations, was modeled using the King County Runoff Time Series (KCRTS) program. The KCRTS program offers a calculation method for evaluating flow durations that are central to the detention requirements set forth in the manual. Sand filter sizes were also evaluated using KCRTS. The KCRTS hydrographs corresponding to the 2-year recurrence interval peak flow discharged from detention facilities were routed through the KCRTS infiltration basin sizing routine, with vertical permeabilities corresponding to sand as opposed to soil, to determine the sand filter bed area needed to effectively treat those design flows. Infiltration facilities were sized using a spreadsheet based on Darcy's Law and the 100-year SBUH storm event hydrographs. The spreadsheet enabled confirmation of the time limits required for water level drawdown following design storm events.

2. Sample Sites and Associated Construction SWPPPs and Permanent Stormwater Site Plans

This section describes the three hypothetical development sites and provides details of corresponding construction SWPPPs and permanent stormwater site plans. Plan elements were chosen to provide examples of elements that satisfy the minimum requirements outlined in the manual. Also provided are implementation costs to satisfy the minimum requirements and operation and maintenance requirements and costs.

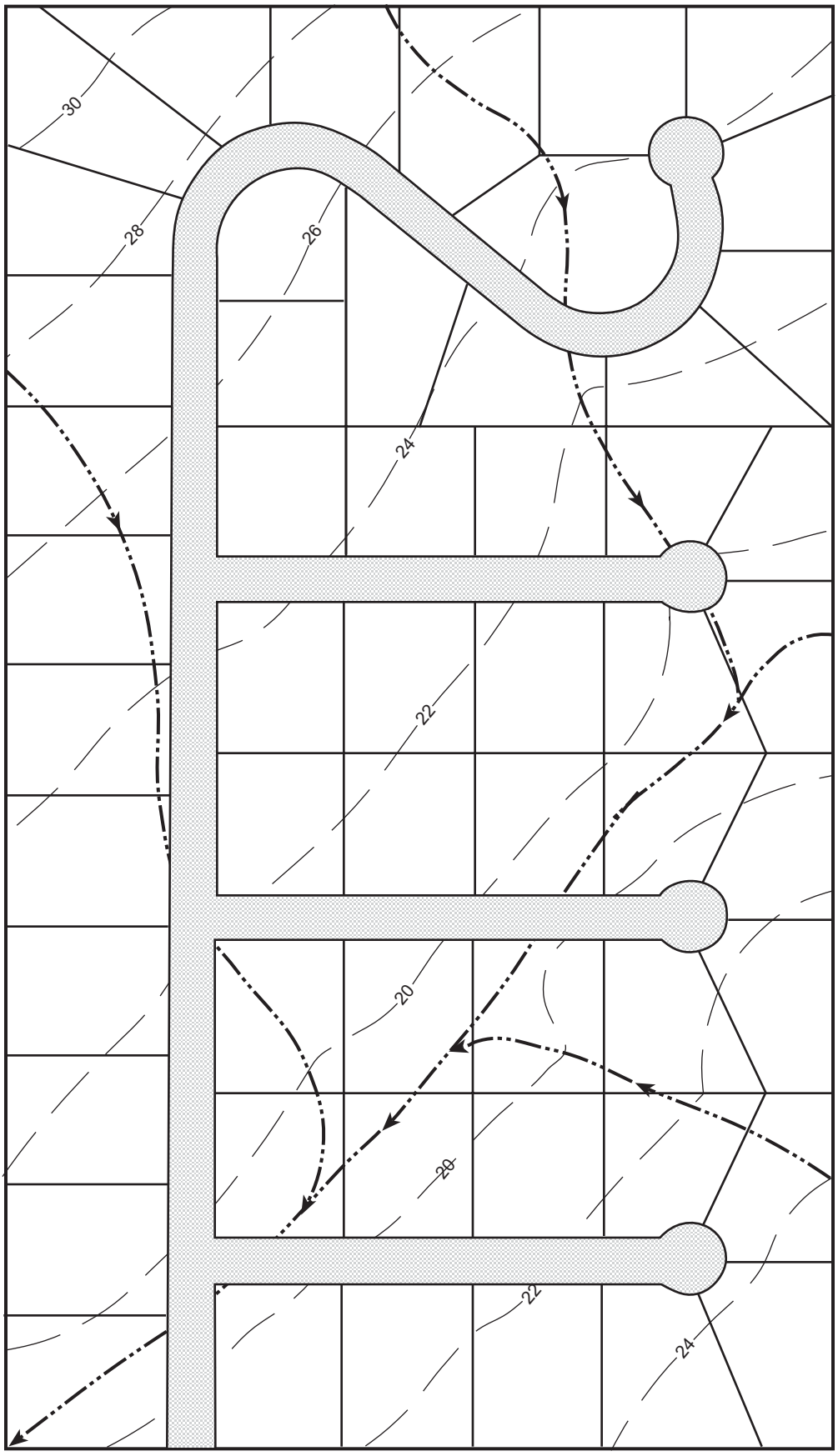
Site 1—Single-Family Residential Development

Site 1 is a 10-acre single-family residential development with 5.5 dwelling units per acre. Figure 1 shows the layout of the site as planned for development without stormwater control facilities to satisfy the minimum requirements. There is one entrance to the development. The topography of the site in its undeveloped state causes runoff to flow to the lower left-hand corner via a few defined drainage courses, the largest of which is indicated near the bottom of the plan view shown in Figure 1. These drainage courses are not streams and provide negligible ecological benefits. Because the development plan does not include extensive regrading of the slopes on the site, drainage would proceed in the same general direction after development. It is assumed that after development, any treated runoff (see below for treatment plans) from the site that does not infiltrate into the soil would be conveyed downstream of the site to a stream. An important distinction between this site and the other two sites analyzed in this report is that surface runoff discharged from a single-family residential development to a fish-bearing stream does not require "enhanced treatment" according to the manual requirements.

The topographic layout of site 1 is conducive to stormwater runon from adjacent land and through-flow in the main drainage course. It is assumed that a decision would be made to minimize the size (and cost) of temporary erosion and sediment control facilities and of permanent stormwater management facilities by separating the offsite runon from the onsite drainage. For the purposes of this analysis it is assumed that one or more culverts and/or intercepting ditches (or similarly effective diversion/conveyance facilities) would be provided to convey those flows around the site. Because these provisions are necessary due to hypothetical site conditions, costs are not included for them.

Site 1 Construction Stormwater Pollution Prevention Plan

For all new development and redevelopment projects that add or replace 2,000 square feet or more of impervious surface or clear more than 7,000 square feet, such as site 1, the manual requires preparation of a SWPPP (minimum requirement two) to guide selection and implementation of a variety of BMPs during construction. The minimum requirements for stormwater pollution prevention during construction include the following 12 elements:



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0 50 100
APPROXIMATE SCALE IN FEET

Figure 1. Ten-acre residential development plan, without stormwater facilities, superimposed on natural (pre-development) topography and drainage features.

1. Mark clearing limits
2. Establish construction access
3. Control flow rates
4. Install sediment controls
5. Stabilize soils
6. Protect slopes
7. Protect drain inlets
8. Stabilize channels and outlets
9. Control pollutants
10. Control de-watering
11. Maintain BMPs
12. Manage the project

It is assumed that construction would require 12 months of site work to complete. Two versions of a SWPPP were evaluated for the condition with type C soils on this site, one accounting for a stoppage of site grading activities from November through March (i.e., assuming that the project would be managed to greatly minimize potential for water quality problems in the wet season) and the other assuming that construction would proceed through the winter months. Thus, the total duration of construction for one SWPPP scenario is 17 months, and for the other SWPPP scenario is 12 months. For both cases it was assumed that the contractor would build the entire 10-acre residential development (houses included), rather than grading the site, providing basic infrastructure and utilities, and leaving individual building sites for future contractors. The comparison of SWPPP costs with and without a winter shutdown is made only for the site condition with type C soils. Type A soils are often associated with construction site erosion problems, and concerns for seasonal clearing and grading restrictions, but type C soils are typically more conducive to turbidity problems. This analysis reflects the likelihood that seasonal clearing and grading restrictions would be more common in type C soils. Of the 12 elements listed above, the only one that would not incur measurable costs in the context of this cost analysis is element 9. The potential opportunity cost to the developer of managing the project to avoid grading activity in the winter was not assessed for this study.

To control transport of sediments off the site and to protect downstream properties and waterways during construction, a combination of BMPs would be used including fenced clearing limits, stabilized site roads, equipment parking areas, storm drain inlet protection on the adjacent street, temporary ground cover in disturbed areas, stabilized conveyance ditches, a large sediment pond, and silt fencing. To satisfy the minimum requirements, these BMPs would be in place prior to beginning construction activities. It is assumed that de-watering would be required at this site, and that those flows could be managed effectively with a filtration device such as a dewatering filter bag or pipe filter sock and then discharged from the site. Therefore, the sizing of sedimentation facilities did not account for de-watering discharges.

Figure 2 shows the locations of the erosion and sediment control BMPs selected for the residential development site. The BMPs are the same for outwash (type A) soils (suitable for infiltration) and till (type C) soils (unsuitable for infiltration). However, the size of the temporary sediment pond differs because of the effect soil type has on runoff peak flows and volumes. The manual specifies that sediment ponds be designed based on the 2-year, 24-hour storm peak runoff flow rate. The 2-year post-developed peak runoff rate used for sediment pond sizing is estimated to be 0.48 cubic feet per second (cfs) with outwash soils (i.e., Type A soils) on the site, and 0.62 cfs with till soils on the site (i.e., type C soils). Figure 2 indicates the sediment pond size corresponding to type C soils. Silt fencing would be used as a divider within the temporary sediment pond to enhance the removal of suspended sediments.

Temporary interceptor swales and conveyance channels lined with suitable geotextiles or organic blankets, or stabilized with seed and mulch, would be used to convey all site runoff to the sediment pond. Silt fencing would be used on downslope edges of the site boundary to prevent sediment discharge. The site entrance would be stabilized with quarry spalls (large rocks), and construction roads on the site and one main parking/staging area would be stabilized with crushed rock. Mulch would be applied extensively to areas of exposed soil during staged construction.

Other BMPs such as vehicle tire washing, occasional street sweeping, and spraying of dusty areas would be implemented during construction. For the scenario where grading work is stopped for the period of November through March it is assumed that greater attention to soil stabilization (such as application of polyacrylamides on a large area) would be needed to prevent erosion on disturbed ground for several months, particularly in Type C soils. For the scenario where grading work occurs through the winter months it is assumed that greater attention to sediment pond maintenance, street sweeping, vehicle tire washing, and replacement of storm drain inlet protection devices would be needed. Following construction of homes on the site, grassed lawns would be planted, and sidewalks and streets would be paved to permanently stabilize disturbed areas.

Maintenance of the erosion and sediment control BMPs is a key component of the construction SWPPP. It is assumed that routine BMP maintenance checks would be performed once weekly and after runoff-producing storm events during the dry season, and daily during the wet season to ensure that BMPs continue to function effectively. The sediment pond must be checked periodically for sediment buildup, especially following storms. Excess sediment accumulation must be removed from the pond and disposed of off the site or spread in a controlled location on the site. Silt fencing must be checked periodically, especially following storms, to determine if repairs or replacement fabric sections are needed. Mulch used to cover stripped site areas would be relocated and replaced as needed, as portions of the site are permanently stabilized. If sediment is tracked offsite onto neighboring streets, it must be swept and collected as necessary.

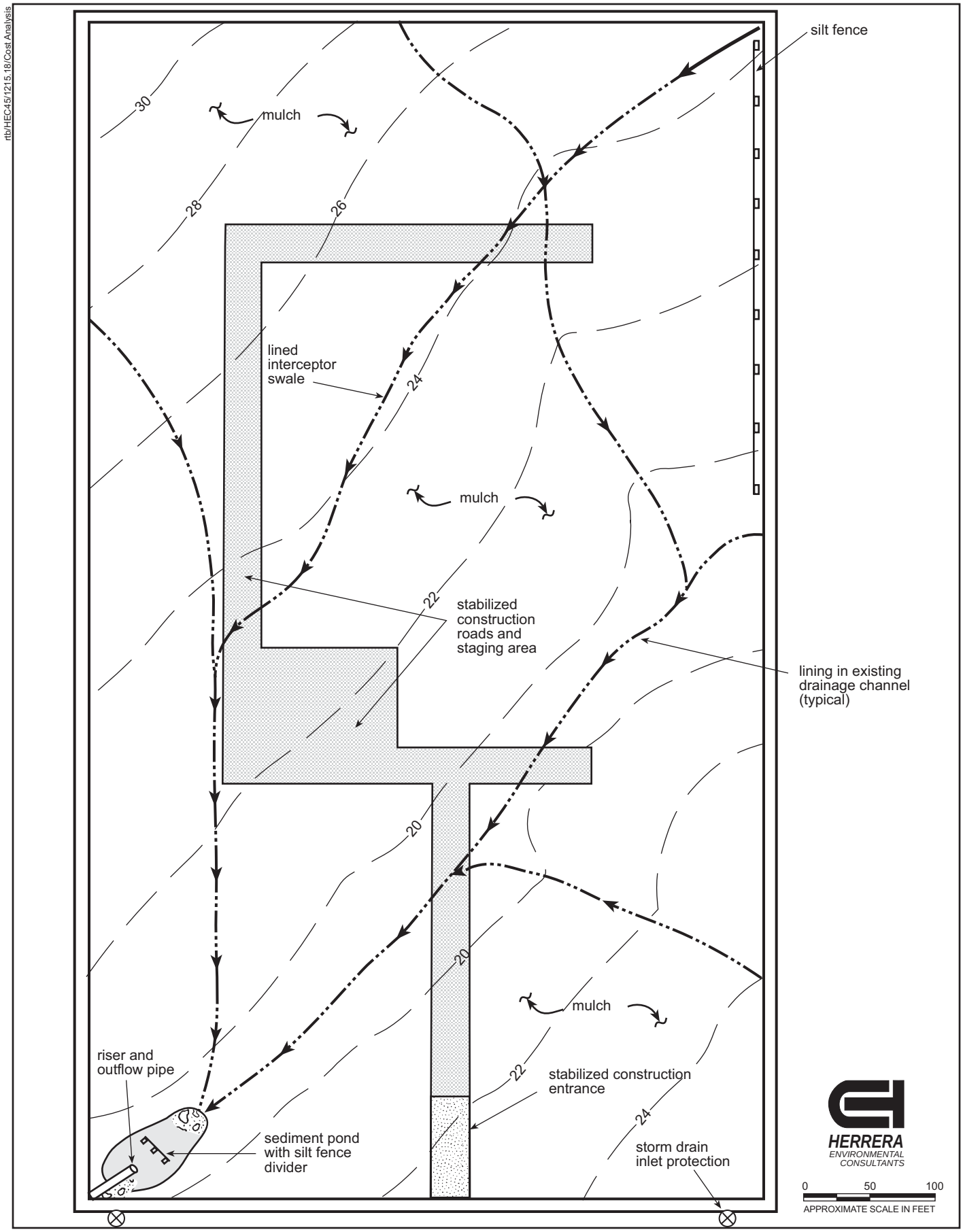

Figure 2. Erosion and sediment control BMPs for 10-acre residential development.

Costs for Construction Stormwater Pollution Prevention Plan

Without Wet Season Shutdown

For the scenario where it is assumed that grading activity continues on the site through the winter, the construction cost for the SWPPP BMPs is estimated at approximately $40,000 for type A soils and $49,000 for type C soils. Tables 1 and 4 in Appendix A, respectively, show itemized costs for the various BMP components and their associated construction procedures and materials. These costs do not include engineering planning and design fees, permit fees, performance bonding (or other appropriate financial instruments to ensure compliance with the approved SWPPP), and contingencies for unforeseen difficulties. Maintenance of the erosion and sediment control BMPs (included in the SWPPP BMP costs noted above) over the course of the 12-month construction period is estimated to cost approximately $8,400 for type A soils and $14,500 for type C soils (see Tables 3 and 7, respectively, in Appendix A). Appendix A provides further details on assumptions used to develop these costs.

With Wet Season Shutdown

For the scenario where it is assumed that the site is managed to avoid grading activity from November through March, the construction cost for the SWPPP BMPs is estimated at approximately $41,000 for type C soils. Table 5 in Appendix A shows itemized costs for the various BMP components and their associated construction procedures and materials. These costs do not include engineering planning and design fees, permit fees, performance bonding (or other appropriate financial instruments to ensure compliance with the approved SWPPP), and contingencies for unforeseen difficulties. As discussed below, the construction SWPPP costs are rolled into the permanent stormwater site plan costs to create a total implementation cost, and those estimates include engineering, permitting, and contingency costs. Maintenance of the erosion and sediment control BMPs over the course of the 17-month construction period (included in the SWPPP BMP cost noted above) is estimated to cost approximately $9,100 (see Table 8 in Appendix A). Appendix A provides further details on assumptions used to develop these costs.

Effects of Wet Season Site Work on SWPPP Cost

The total SWPPP implementation and maintenance cost varies slightly depending on whether clearing and grading activity occurs in the wet winter months. For the scenario where the site is stabilized for the period of November through March, it is estimated that the total SWPPP cost would be $7,400 less compared to the scenario where site activities continue through the winter. Avoidance of grading activities in the wet season is assumed to result in reduced costs for street sweeping, BMP inspections following storms, and catch basin cleaning, but increased cost for soil stabilization during the winter. Most of the SWPPP costs are independent of work scheduling in the wet season for this site. For example, the sedimentation pond size, the need for temporary lined conveyance ditches, and the need for stabilization of construction roads and construction staging areas are the same regardless of wet season work scheduling.

Site 1 Permanent Stormwater Site Plan

The stormwater site plan must include provisions for maintaining natural drainage patterns, using source control BMPs to prevent pollutants from entering stormwater runoff, reducing hydrologic changes through onsite stormwater management techniques, treating runoff from smaller storm events, detaining runoff from larger storm events to prevent stream bank erosion due to high flows, and maintaining the BMPs that are chosen and implemented. Minimum requirement eight, pertaining to wetlands, and minimum requirement nine, pertaining to basin planning, are assumed to be not applicable to this hypothetical site and this analysis. In accordance with the manual, two preliminary considerations guided BMP selection for site 1. Oil control and special phosphorus control measures must be considered; they are not required for this site. The standard western Washington peak flow control to match pre-development flow peaks and durations must be considered and is required because the site discharge is conveyed to a small stream (if site discharge is conveyed directly to a major water body, the standard does not apply).

Pollution Source Control BMPs

Pollution source control BMPs are important components of a stormwater site plan for site 1 to satisfy minimum requirement three. Several of the source control BMPs outlined in the manual are applicable to this development. However, only a few of the source control BMPs that should be applied to this development incur direct, calculable costs. Source controls such as environmentally sensitive vegetation management and protection of storage areas housing containers for chemicals, garbage, and other wastes are important and should be emphasized to homeowners. However, they are difficult to quantify in terms of costs. Moreover, some of these source controls are not required for residences. An actual stormwater site plan for this type of residential development site should mention these items; however, the cost estimates given herein do not include costs to implement source control BMPs that are educational in nature, as opposed to physical actions. The cost estimates for this site include only two source control BMPs from the manual: maintenance of storm drainage facilities (BMP S2.00) and street sweeping (BMP S2.20).

Onsite Stormwater Management Measures

In addition to pollution source control BMPs, onsite stormwater management measures must also be implemented to infiltrate, disperse, and retain stormwater runoff onsite where practicable (minimum requirement number 5). Some examples of onsite stormwater management BMPs applicable to this residential development include roof downspout infiltration and dispersion, use of permeable/porous pavements, and vegetated rooftops. For this site, the use of "alternative" roof downspout infiltration trenches was assumed with infiltratable soils on site (type A). These infiltration systems are suitable for coarse soils, and have a simpler design than downspout infiltration systems in soils with fine particles. Permanent stormwater facilities were sized, and the associated cost estimate developed, with roof downspout infiltration included. The contributing drainage area for the permanent pond facilities is considerably reduced as a result.

For the scenario with noninfiltratable type C soils, it was assumed that roof downspout dispersion systems would be provided for half of the total rooftop areas. The sizing of permanent stormwater treatment and flow control facilities accounted for 50 percent of the rooftop runoff, assuming that 50 percent could be dispersed through sufficient grassy areas and that the other 50 percent of the rooftop runoff would drain relatively quickly to conveyance systems carrying flow to the stormwater pond facilities. If all rooftop runoff could pass through grassy areas greater than 50 feet in length, the modeling of site runoff could assume that all of the rooftops are equivalent to grass and the size of the stormwater pond facilities would be reduced accordingly. The cost estimate for rooftop drainage dispersion systems assumes simple splashblocks that disperse flow across a long grassy area as opposed to rock-filled trenches with notched grade boards. Although it was assumed that porous pavements could be used for individual driveways, the sizing of the permanent stormwater treatment and flow control facilities conservatively assumed that all driveway runoff would reach the ponds relatively quickly. Thus, the cost estimate for this scenario is representative of a worst-case for the amount of flow to be managed. If earth-filled concrete paver blocks or similar materials were used for driveways, the modeling of site runoff could assume that 50 percent of the driveway areas are equivalent to grass and the size of the stormwater pond facilities would be reduced accordingly.

Permanent Stormwater Control Facilities by Soil Type

The permanent stormwater control facilities selected for the residential site to satisfy the minimum requirements are dependent on soil type.

Type A Soils – With Infiltration

Infiltration is the preferred method of stormwater treatment and surface flow reduction, but infiltration requires suitable soils. For the scenario with type A soils, an infiltration basin preceded by a wetpond provides stormwater treatment and flow control. Figure 3 shows the layout of the site with the permanent stormwater control facilities for this condition.

While type A soils are suitable for discharging the site runoff to ground water, they are too porous to accomplish water quality treatment. The design includes a wetpond that performs water quality treatment and serves as a presettling facility in front of the infiltration basin. The wetpond is designed to treat all runoff from the 6-month, 24-hour storm event and is divided into two separate cells. Both wetpond cells would be excavated approximately 6 feet below grade, with an additional foot of depth in the first cell for sediment storage.

The infiltration basin, which would also be excavated 6 feet below grade, was sized to completely infiltrate all runoff up to the 100-year, 24-hour storm event, even though in pre-developed conditions there would be slight runoff from the site in extreme storm events. The wetpond overflows to the infiltration basin, and the infiltration basin has an overflow structure for safe conveyance of extreme high flows.

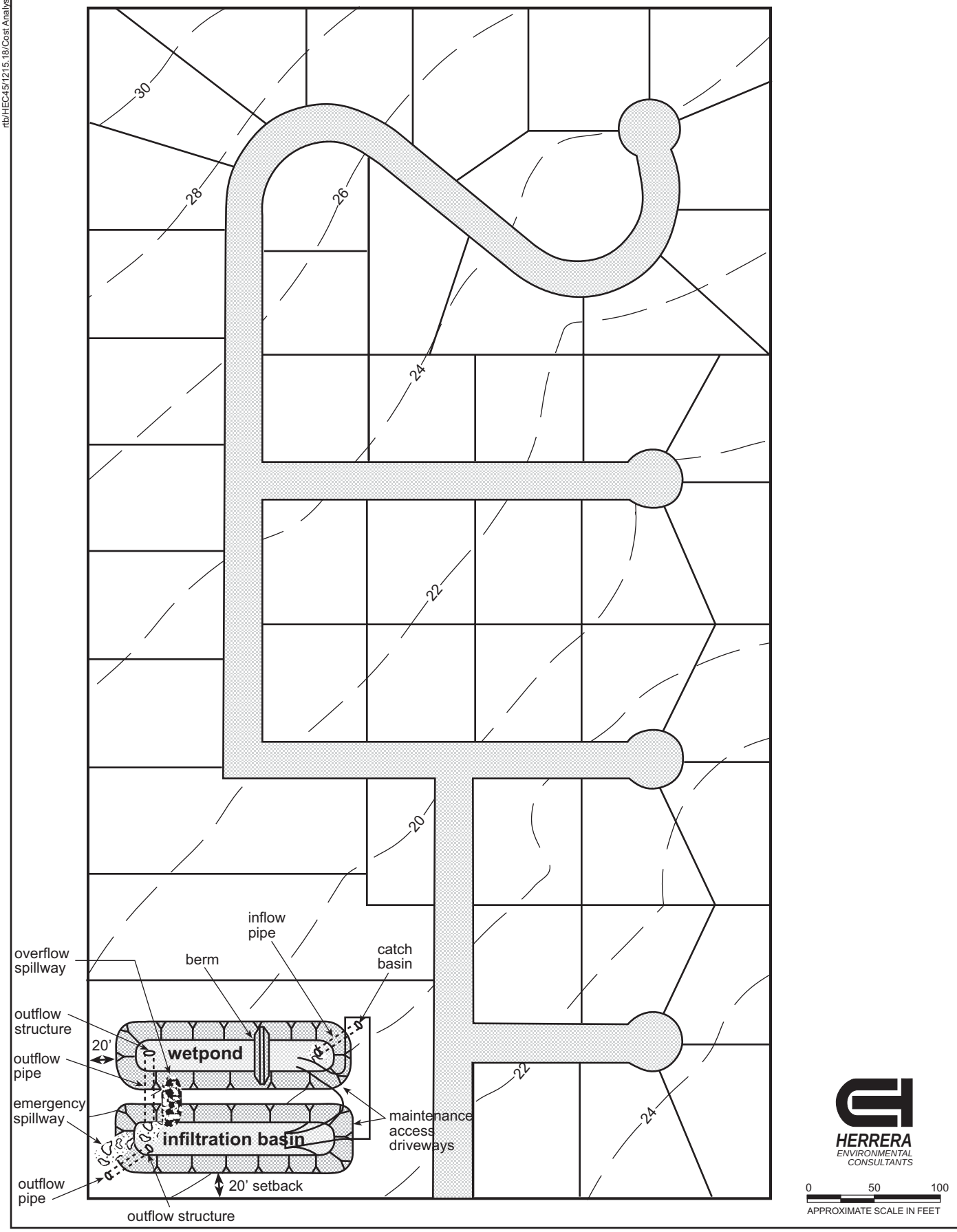

Figure 3. Permanent stormwater site plan BMPs for 10-acre residential development with infiltration.

Type C Soils– Without Infiltration

The scenario without infiltration (type C soils) contains a combined wet/detention pond with a permanent pool for water quality treatment and excess storage capacity for peak flow control. Figure 4 shows the layout of the site with the permanent stormwater control facilities for this condition. The pond does not require special design features for enhanced phosphorus removal.

The center of the pond is a permanent treatment pool with two cells separated by an earthen berm. The first cell is excavated approximately 10 feet below existing grade, and the second cell is excavated nine feet below grade. Each cell provides four feet of water depth to create a permanent pool (during the wet months) for water quality treatment. The first cell has an additional one foot of sediment storage capacity in the bottom. An additional four feet of storage space on top of the permanent pool provides detention capacity for the 100-year runoff event. The extra foot of freeboard allows for an emergency overflow spillway. The outer portion of the pond, which surrounds the permanent pool, provides detention storage. Because the detention storage volume needed is large in relation to the water quality treatment volume needed, the pond footprint area expands significantly in the upper detention zone. The pond has a multiple-orifice outflow restrictor above the permanent pool level to maintain predevelopment site discharge rates and flow durations.

The permanent BMP facilities, both with infiltration and without infiltration, are located so that they receive runoff from the entire development and maintain the natural drainage pattern of the site. The excavation for the temporary sediment pond is expanded for the permanent stormwater control facilities. A catch basin is provided at the site discharge location; it is assumed that the catch basin outflow is piped into the storm drainage system adjacent to the site.

Site 1 Implementation Costs to Satisfy the Minimum Requirements

Costs With Infiltration

The total cost of planning, designing, and constructing the BMPs in the construction SWPPP and permanent stormwater site plans for the scenario with infiltration is estimated at approximately $240,000, including engineering design and permitting costs, contingencies (25 percent of the total construction cost), and tax on the total cost with contingencies. The total cost for the scenario with the infiltration basin also includes the cost of performing a hydrogeologic evaluation to confirm infiltration suitability and/or determine the site-specific infiltration rate. The cost of the permanent stormwater facilities in the stormwater site plan is approximately 64 percent of the total implementation cost.

Costs Without Infiltration

The total cost of planning, designing, and constructing the BMPs in the construction SWPPP and permanent stormwater site plans for the scenario without infiltration is estimated at approximately $230,000. The cost of the permanent stormwater facilities in the stormwater site plan under this scenario is approximately 60 percent of the total implementation cost.

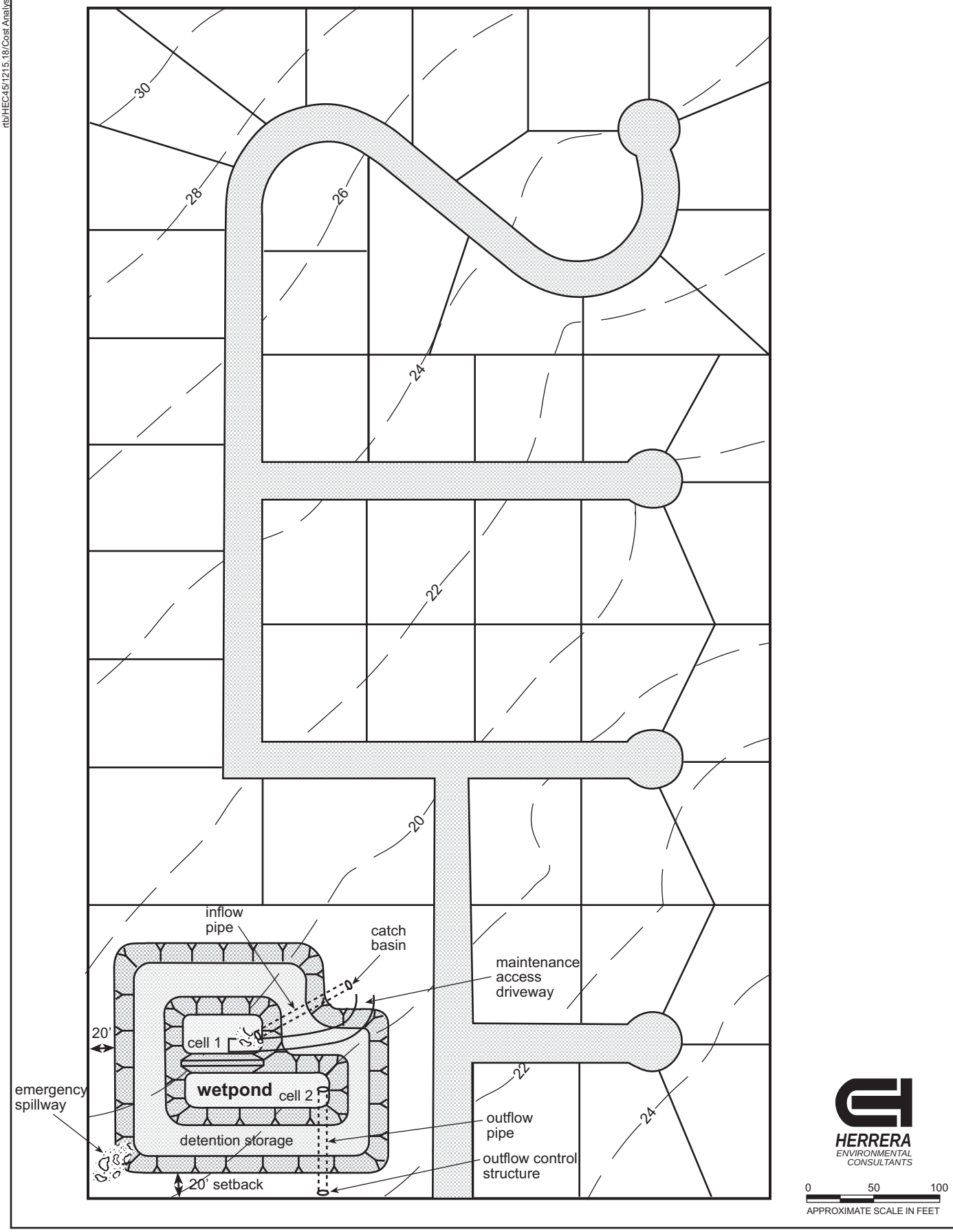

Figure 4. Permanent stormwater site plan BMPs for 10-acre residential development without infiltration.

Itemized costs for the components of the stormwater site plan are given for the two scenarios in Tables 2 and 6 of Appendix A. Appendix A also provides further details on assumptions used to estimate costs.

Comparison of Pond Storage Volumes to 1993 Estimates

For the scenario where infiltration is feasible in type A soils and a wetpond is used for treatment of the runoff prior to infiltration, both the wetpond and the infiltration basin are now smaller in comparison to the sizes under the 1992 requirements. This is due to the requirement for onsite stormwater management (roof downspout infiltration). The volume of runoff assumed to reach the wetpond and infiltration basin is significantly less in comparison to the calculations associated with the 1992 requirements. The wet/detention pond in type C soils analyzed in this case study is larger in size compared to the same type of facility analyzed for this same site scenario in the 1993 report (Herrera 1993). This is because the wetpond storage volume has increased as a result of the design criteria for the 6-month storm precipitation depth and the detention storage volume has increased considerably as a result of the requirement to match flow durations in addition to controlling peak flow rates.

The comparison of pond storage volumes in type A soils is as follows:

- 1993 analysis (re-analyzed as discussed in Appendix C) -- wetpond treatment pool volume = 23,950 cubic feet; infiltration basin storage volume = 60,900 cubic feet
- Present analysis -- wetpond treatment pool volume = 13,700 cubic feet; infiltration basin storage volume = 41,900 cubic feet;

The comparison of these storage volumes in type C soils is as follows:

- 1993 analysis -- wetpond treatment pool volume = 25,700 cubic feet; detention storage volume = 50,300 cubic feet; total pond storage volume = 76,000 cubic feet
- Present analysis -- wetpond treatment pool volume = 28,600 cubic feet; detention storage volume = 98,000 cubic feet; total pond storage volume = 127,000 cubic feet

Site 1 Operation and Maintenance Requirements and Costs

Operation and Maintenance Assumptions

Routine maintenance of the permanent stormwater facilities includes such tasks as conducting annual inspections; mowing the grass in the infiltration basin and wetpond, or combined wet/detention pond, at least twice per year; removing accumulations of debris and floating materials once per year; removing accumulated sediments in the wetpond once the sediment storage depth in the bottom is full (assumed to be once every 5 years); tilling the infiltration

basin soil or otherwise re-establishing maximum infiltration capacity as needed (assumed to be once every 2 years); seeding of grassed areas that turn bare at least once per year; adding quarry spalls and/or gravel to overflow spillways and access driveways as needed; replacing miscellaneous parts and materials as needed; and cleaning out connecting pipes. In addition, streets within the development should be swept frequently to limit the amount of sediment that enters the permanent stormwater control facilities, enabling them to function more effectively. All catch basins and storm drains in the development should be cleaned frequently to prevent clogging and to remove some of the pollutants that otherwise could be flushed into the treatment and detention facilities during large storm events.

Operation and Maintenance Costs, With and Without Infiltration

The annual cost of routine maintenance procedures for the scenario with the infiltration basin and wetpond is estimated at $7,200 (see Table 3 in Appendix A). The annual maintenance cost for the scenario with a combined wet/detention pond (without infiltration) is estimated at $9,000 (see Tables 7 and 8 in Appendix A). Most of the annual operation and maintenance costs are associated with street sweeping and conveyance system cleaning rather than pond maintenance.

Further details on assumptions used to estimate operation and maintenance costs are given in Appendix A.

Site 2—Small Commercial Development

Site 2 is a 1-acre commercial development assumed to be a typical restaurant. Figure 5 shows the layout of the site as planned for development, without stormwater control facilities to satisfy the minimum requirements. The site has 90 percent impervious cover. There is one main site entrance for construction access (see Figure 6). This relatively flat site drains from the upper left to the lower right (as shown in Figure 5) in its undeveloped state, with the potential for stormwater runon from adjacent land. Because the site would not be graded extensively, after development drainage would flow in the same direction.

It is assumed that the developed site would have underground storm sewer pipes to convey runoff to the permanent stormwater control facilities. It is assumed that some mechanism is provided to divert offsite runoff around the site (such as that mentioned for the residential site), the costs of which are not included in this analysis. It is also assumed that developed site runoff that is not infiltrated is discharged to an offsite storm sewer, eventually reaching a stream.

Site 2 Construction Stormwater Pollution Prevention Plan

For all new development and redevelopment projects that add or replace 2,000 square feet or more of impervious surface or clear more than 7,000 square feet, such as site 2, the manual requires preparation of a SWPPP to guide selection and implementation of a variety of BMPs during construction. The 12 minimum requirements for stormwater pollution prevention during construction are listed above for site 1. It is assumed that construction would take 2 months to complete.

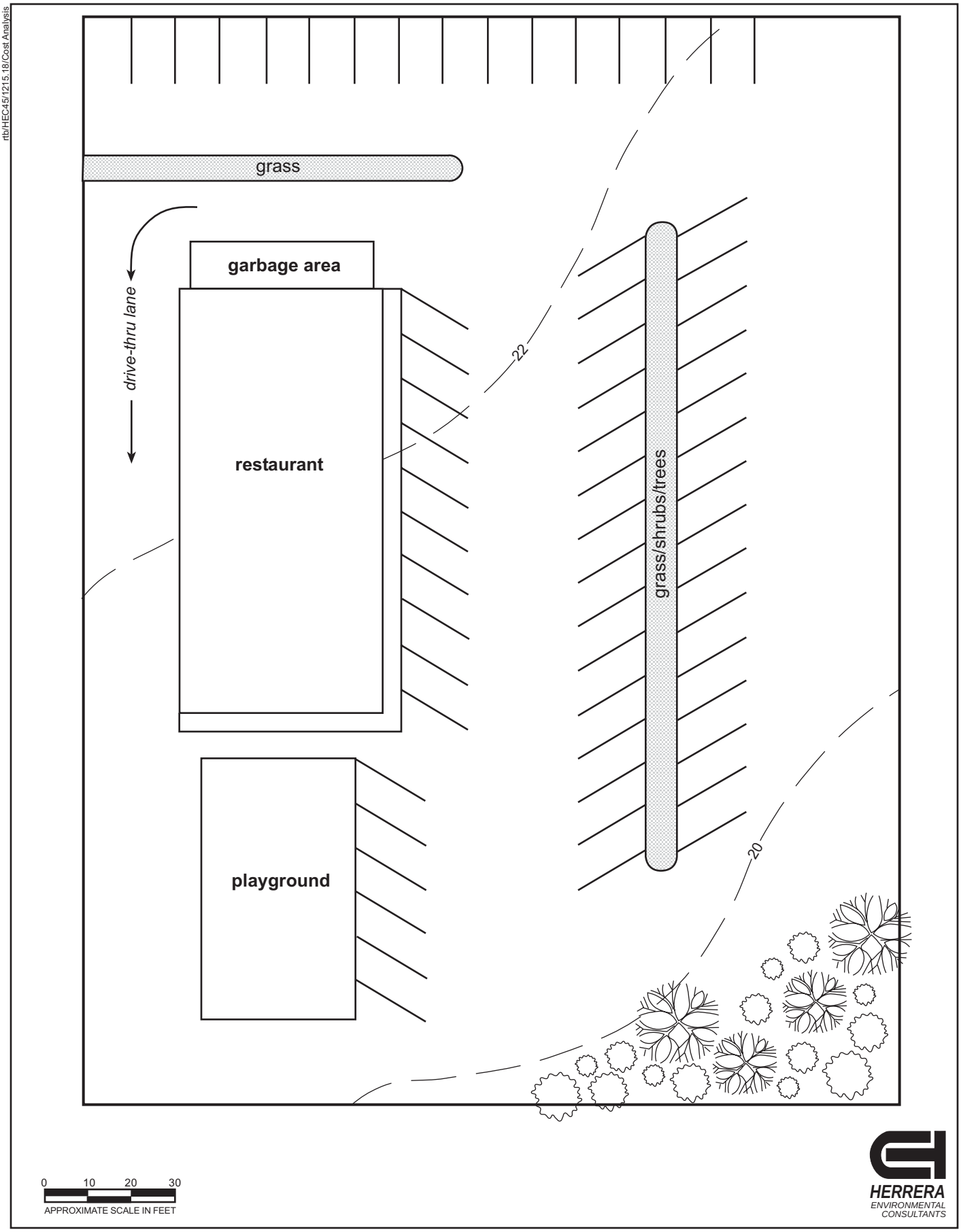

Figure 5. One-acre commerical development plan, without stormwater facilities, superimposed on natural (pre-development) topography and drainage features.

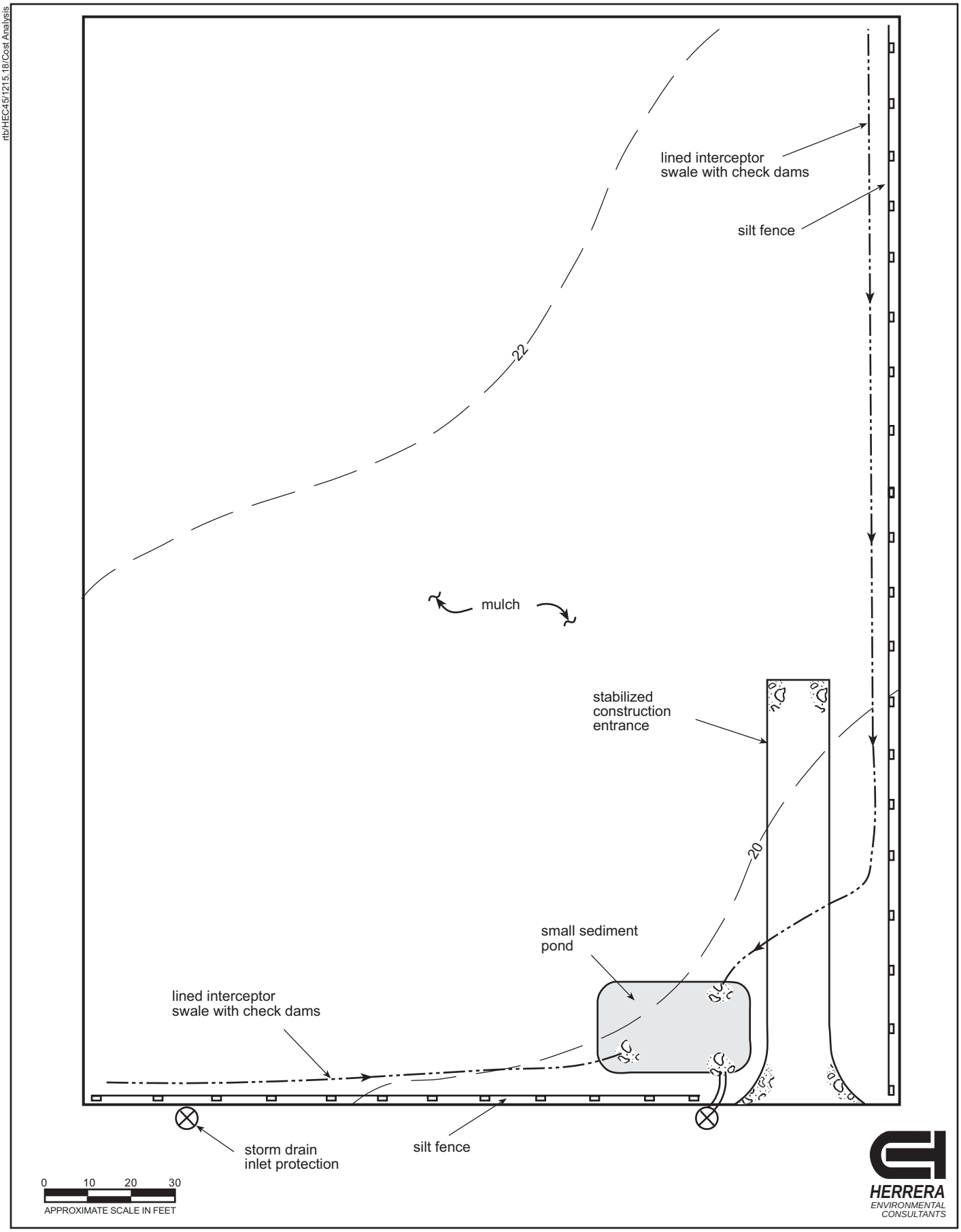

Figure 6. Erosion and sediment control BMPs for 1-acre commercial development.

Several BMPs are necessary to control site runoff and erosion during the construction phase of site 2. A combination of intercepting swales with check dams, a small sediment pond, a stabilized site entrance and equipment parking area, mulch application to bare areas, storm drain inlet protection on the adjacent street, and silt fencing on the downslope perimeter would be used to control transport of sediments off the site and to protect downstream properties and waterways during construction. These BMPs would be in place prior to construction activities to satisfy the minimum requirements.

Figure 6 shows the locations of the erosion and sediment control BMPs selected for the small commercial development site. The BMPs are almost all the same for type A soils (suitable for infiltration) and type C soils (unsuitable for infiltration). The size of the temporary sediment pond differs for the two soil types because of the effect soil type has on runoff peak flows and volumes. Figure 6 indicates the sediment pond size corresponding to type C soils, which is larger than the pond for type A soils.

It is assumed that interceptor swales for runoff collection would not be needed in type A soils. The intercepting swales along the edges of the site would be used to convey almost all of the construction site runoff to the sediment pond (in type C soils). The sediment pond would contain a silt fence divider to enhance trapping of suspended sediments. Silt fencing would be used to contain sediments on the site periphery that may be present in runoff that does not reach the interceptor swales. The site entrance would be stabilized with quarry spalls. Mulch would be applied as needed to areas of exposed soil during construction.

It is assumed that two catch basins on the adjacent street would require inlet protection. Due to the relatively short time frame for construction, it is assumed that cleaning of the catch basins on the adjacent street would not be necessary following construction, and that the small sediment pond would not require sediment cleanout prior to its removal. Other BMPs such as vehicle tire washing and spraying of dusty areas would be implemented during construction as needed.

Maintenance of the erosion and sediment control BMPs is a key component of the construction SWPPP. It is assumed that routine BMP maintenance checks would be performed once weekly and after runoff-producing storm events during the dry season, or daily during the wet season to ensure that BMPs continue to function effectively. Silt fencing must be checked periodically, especially following storms, to determine if repairs or replacement fabric sections are needed. Mulch used to cover stripped site areas would be relocated and replaced as needed, as portions of the site are permanently stabilized. If sediment is tracked offsite onto neighboring streets, it must be swept and collected as necessary.

Costs for Construction Stormwater Pollution Prevention Plan

The construction cost for these SWPPP BMPs is estimated at approximately $6,900 for type A soils and $8,600 for type C soils. Tables 9 and 12 in Appendix A show itemized costs for the various BMP components and their associated construction procedures and materials. These costs do not include engineering planning and design fees, permit fees, performance bonding (or other appropriate financial instruments to ensure compliance with the approved SWPPP), and

contingencies for unforeseen difficulties. Maintenance of the erosion and sediment control BMPs over the course of the 2-month construction period (included in the SWPPP BMP costs noted above) is estimated to cost approximately $1,300 for type A soils and $1,900 for type C soils (see Tables 11 and 14 in Appendix A, respectively). Appendix A provides further details on assumptions used to develop these costs.

Site 2 Permanent Stormwater Site Plan

The stormwater site plan must include provisions for maintaining natural drainage patterns, using source control BMPs to prevent pollutants from entering stormwater runoff, reducing hydrologic changes through onsite stormwater management techniques, treating runoff from smaller storm events, detaining runoff from larger storm events to prevent stream bank erosion due to high flows, and maintaining the BMPs that are chosen and implemented. Minimum requirement eight, pertaining to wetlands and minimum requirement nine, pertaining to basin planning are assumed to be not applicable to this hypothetical site and this analysis.

In accordance with the manual, two preliminary considerations guided BMP selection for site 2. Oil control is assumed to be required for this site due to high vehicle turnover rates that meet the high use site definition. Phosphorous control is not required. The standard western Washington peak flow control to match pre-development flow peaks and durations is required because the site discharge is conveyed to a small stream (if site discharge is conveyed directly to a major water body, the standard does not apply).

Pollution Source Control BMPs

Pollution source control BMPs are important components of the stormwater site plan for site 2 to satisfy minimum requirement three. Several of the source control BMPs outlined in the manual are applicable to this development. The area designated for garbage containers adjacent to the restaurant should be covered or contained to prevent precipitation from contacting waste containers and to prevent the runoff from entering the nearby storm drainage system. The interior of this area must drain to the sanitary sewer if possible (BMP S1.50). Other materials and wastes that may introduce pollutants to stormwater should also be placed in the protected area. Cooking equipment such as vents and filters must not be cleaned outdoors unless a sanitary sewer drain is provided. In addition, storm drainage facilities must be maintained (BMP S2.00), and the parking lot should be swept frequently to collect and properly dispose of accumulated sediments and other materials that may contain pollutants (BMP S1.22).

Onsite Stormwater Management Measures

In addition to pollution source control BMPs, onsite stormwater management measures must also be implemented to infiltrate, disperse, and retain stormwater runoff onsite where practicable (minimum requirement five). Some examples of onsite stormwater management BMPs applicable to this commercial development include roof downspout infiltration, use of permeable/porous pavements in low traffic areas, and vegetated rooftops. For this site, the use of

"typical" roof downspout infiltration trenches (with inlet catch basins and perforated pipe) was assumed with infiltratable soils on site (type A). The simpler ("alternative") infiltration trench design that is allowed in coarse soils, as assumed for Site 1, would require a wide strip of grass between the building and the trenches, and this type of site would not likely have available space for such a grass strip. Permanent stormwater facilities were sized, and the associated cost estimate developed, with roof downspout infiltration included.

For the scenario with type C soils, it was assumed that roof downspout dispersion systems would not be feasible due to limited area of grass or other open space. The sizing of permanent stormwater treatment and flow control facilities accounted for all rooftop runoff because it was assumed that this runoff would reach the stormwater control vaults quickly. Although it was assumed that porous pavements could be used for low traffic areas of the site, the sizing of the permanent stormwater treatment and flow control facilities conservatively assumed that all driveway and parking lot runoff would reach the vaults quickly.

Permanent Stormwater Control Facilities by Soil Type

The permanent stormwater control facilities selected for the small commercial development site to satisfy the minimum requirements are dependent on soil type. Regardless of soil type, it is assumed that the stormwater facilities would be placed underground to maximize surface area for vehicle parking. This is a departure from the assumption in the 1993 cost analysis report (Herrera 1993) that all stormwater management facilities would be placed above ground, regardless of the implications for available parking area, and results in significant cost differences. The oil control requirement also applies regardless of soil type. It is assumed that catch basin filter inserts would be used for this oil control.

Type A Soils – With Infiltration

Infiltration is the preferred method of stormwater treatment and flow control, but infiltration requires suitable soils. For the scenario with type A soils (suitable for infiltration), underground infiltration tanks preceded by a wet vault provides stormwater treatment and flow disposal. Figure 7 shows the layout of the site with the permanent stormwater control facilities for this condition. For cost estimating purposes, it was assumed that two sections of 8-foot diameter asphalt-treated steel pipe would be used to construct the wet vault, and that 5-foot diameter aluminized steel pipe with perforations would be used for the infiltration tanks. These structures would support traffic loads from above provided there is approximately 2 feet of cover beneath the parking lot pavement. The infiltration tanks and associated inflow piping are assumed to store and dispose of all runoff up to the 100-year event even though slight flows occur in the pre-development condition. Steel pipe was assumed for this analysis as a cost saving measure. In many cases concrete vaults may be necessary, and that would lead to increased costs.

Type A soils are not suitable for water quality treatment via infiltration; therefore, a wet vault (discussed below) provides pretreatment for ground water protection. The wet vault also provides protection for the infiltration system by significantly reducing the sediment loading that could potentially clog the infiltration media. With infiltration of all runoff, enhanced treatment is

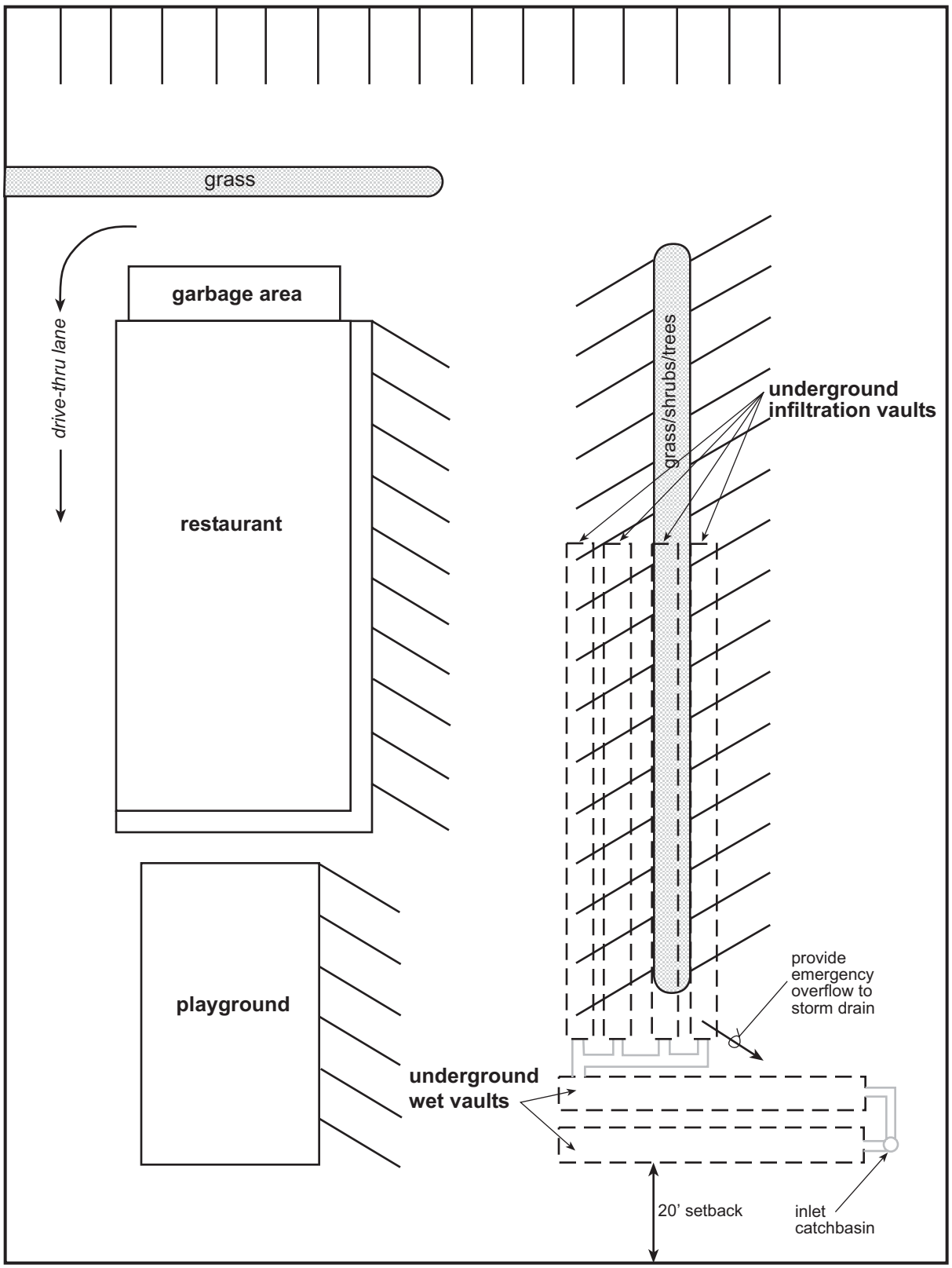

Figure 7. Permanent stormwater quality control BMPs for 1-acre commercial development with infiltration.

not required. It is assumed that downspout infiltration trenches (shown conceptually on Figure 7) would be provided in this scenario. Therefore, the rooftop runoff does not reach the wet vault or infiltration vaults and their sizes are reduced accordingly (by approximately 20 percent).

The wet vault is sized with a treatment pool volume equivalent to the site runoff volume (excluding rooftop area) of the 6-month, 24-hour storm event. This vault overflows to the buried infiltration tanks. Under extreme storm conditions (but less than the 100-year event), flows can back up through the infiltration tanks and wet vault and can be stored in the conveyance piping. The depth of the wet vault treatment pool is assumed to be 6 feet (with 1 foot of sediment storage on the bottom and 1 foot of freeboard on top), and the maximum depth of ponding inside the infiltration tanks is assumed to be 3 feet.

Type C Soils – Without Infiltration

For the scenario without infiltration, a wet vault with a permanent pool performs water quality treatment and adjacent detention pipes provide storage capacity for flow control. An additional sand filter vault provides the enhanced treatment required with a surface discharge to fish-bearing waters. Figure 8 shows the layout of the site with a wet vault, detention pipes, and separate sand filter vault in place. The treatment pool in the wet vault and the sand filter constitute a two-facility treatment train to perform the enhanced water treatment that is required. The wet vault does not require special design features for phosphorus removal. Because the detention storage volume needed is relatively large in comparison to the treatment volume, it is assumed that separate pipes of different diameter provide a detention function only. It is assumed that the wet vault would be built with 8-foot diameter asphalt-treated steel pipe and that the detention storage would be provided by four sections of 5-foot diameter aluminized steel pipe and a connecting manifold system. The detention pipes are of smaller diameter because the bottom elevation of the detention storage is set above the adjacent sand filter bed elevation, and a deeper detention storage outlet would result in a deeper sand filter vault. If the sand filter vault were excessively deep it would probably not be able to drain into the nearby storm sewer system. The detention pipe system is connected to a catch basin with a multiple-orifice outflow restrictor to maintain predevelopment site discharge rates and flow durations. The outlet control structure discharges to the sand filter vault. The sand filter is assumed to be housed in a concrete vault structure comprised of precast sections 20 feet in width and laid parallel, with pipes connecting the parallel vault sections. The sand filter bed is sized to treat the peak 2-year storm flow discharged from the detention system, with a perforated pipe underdrain system to collect treated flows, and flows above the 2-year detained peak would be discharged directly to the nearby storm sewer system via an overflow pipe.

By placing the stormwater management facilities in underground pipes, significantly more parking spaces are available in comparison to the design assumed in the comparable 1993 case study (Herrera 1993). If the facilities were placed above ground there would be insufficient parking area available to justify the development.

The permanent BMP facilities, both with infiltration and without infiltration, are located so that they receive runoff from the entire site and maintain the natural drainage pattern of the site. The

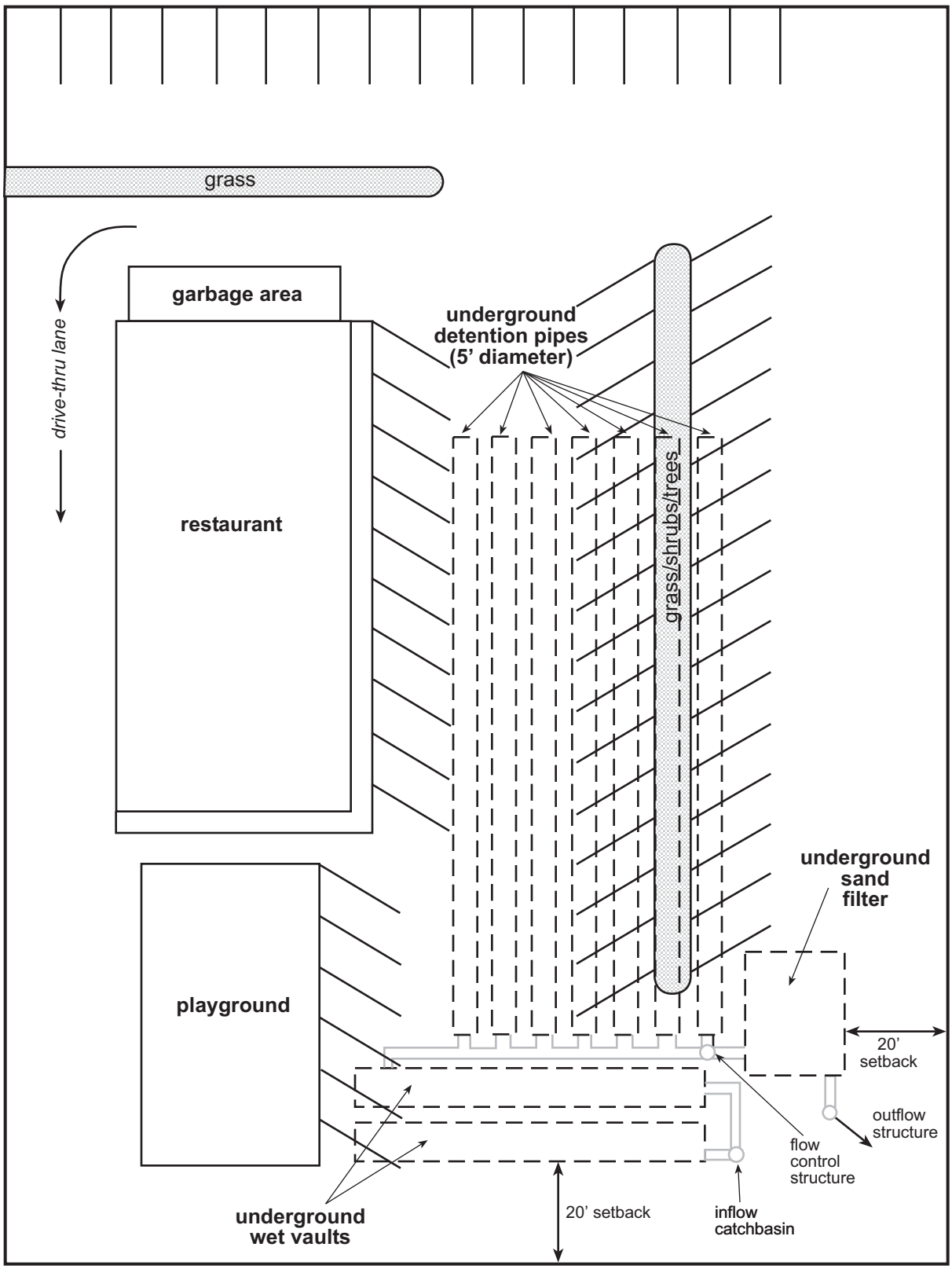

Figure 8. Permanent stormwater quality control BMPs for 1-acre commercial development without infiltration.

excavation site for the temporary sediment pond is partially used for burial of the permanent stormwater control vaults. Emergency overflow facilities are provided for each of the underground vaults. A catch basin is provided at the site discharge location; it is assumed that the catch basin outflow is piped into the storm sewer system adjacent to the site.

Site 2 Implementation Costs to Satisfy the Minimum Requirements

Costs With Infiltration

The total cost of planning, designing, and constructing the BMPs in the construction SWPPP and permanent stormwater site plans for the scenario with infiltration is estimated at approximately $280,000, including taxes and contingencies for unforeseen difficulties. The total cost for the scenario with the infiltration vaults also includes the cost of performing a hydrogeologic evaluation to confirm infiltration suitability and/or determine the site-specific infiltration rate. The cost of the permanent facilities in the stormwater site plan is approximately 95 percent of the total implementation cost.

Costs Without Infiltration

The total cost of planning, designing, and constructing the BMPs in the construction SWPPP and permanent stormwater site plans for the scenario without infiltration is estimated at approximately $570,000. The cost of the permanent stormwater facilities in the stormwater site plan under this scenario is approximately 97 percent of the total implementation cost.

Itemized costs for the components of the stormwater site plan are given for the two scenarios in Tables 10 and 13 of Appendix A. Appendix A also provides further details on assumptions used to estimate costs.

Comparison of Treatment and Detention Storage Volumes to 1993 Estimates

For the scenario where infiltration is feasible in type A soils and a wet vault is used for treatment of the runoff prior to infiltration, the storage volumes in both the wet vault and the infiltration tanks are now smaller in comparison to the sizes under the 1992 requirements. This is due to the requirement for onsite stormwater management (roof downspout infiltration). The volume of runoff assumed to reach the wet vault and infiltration tanks is significantly less in comparison to the calculations associated with the 1992 requirements. The storage volumes in the wet vault and detention pipes in type C soils analyzed in this case study are larger in size compared to the volumes estimated for this same site scenario in the 1993 report (Herrera 1993). This is because the wetpool storage volume has increased as a result of the design criteria for the 6-month storm precipitation depth and the detention storage volume has increased considerably as a result of the requirement to match flow durations in addition to controlling peak flow rates.

The comparison of these storage volumes in type A soils is as follows:

- 1993 analysis (re-analyzed as discussed in Appendix C) – wet vault treatment pool volume = 3,590 cubic feet; infiltration tank storage volume = 9,000 cubic feet

- Present analysis – wet vault treatment pool volume = 3,270 cubic feet; infiltration tank storage volume = 4,780 cubic feet

The comparison of these storage volumes in type C soils is as follows:

- 1993 analysis -- wetpond treatment pool volume = 3,660 cubic feet; detention storage volume = 7,200 cubic feet; total storage volume = 10,800 cubic feet

- Present analysis – wet vault treatment pool volume = 4,150 cubic feet; detention storage volume = 16,300 cubic feet; total storage volume = 20,500 cubic feet

The combination of greater storage volumes, the need for a sand filter to provide enhanced treatment, and placement of the facilities underground results in much greater stormwater management costs in the present analysis compared to the 1993 analysis.

Site 2 Operation and Maintenance Requirements and Costs

Operation and Maintenance Assumptions

Routine maintenance of the permanent stormwater facilities includes such tasks as annual inspections; frequent replacement of the catch basin inserts (assumed to be four times per year for each of four catch basins in the parking lot); tilling the bottom of the infiltration vaults periodically to restore maximum infiltration capacity (assumed to be once every two years); raking the sand filtration surface once the depth of accumulated silt and debris on the surface exceeds ¼ inch (assumed to be once every two years); removing accumulated sediments in the wet vault when the depth exceeds the sediment storage depth (assumed to be once every five years); replacing miscellaneous parts and materials as needed; and cleaning out connecting pipes. In addition, the parking lot should be swept frequently to limit the amount of sediments that enter the permanent stormwater control facilities, enabling them to function more effectively.

Operation and Maintenance Costs, With and Without Infiltration

The annual cost of routine operation and maintenance procedures for the scenario with the wet vault and infiltration tanks is estimated at approximately $4,000. The annual operation and maintenance cost for the scenario with a wet vault, detention pipes, and sand filter vault (without infiltration) is also estimated at approximately $4,000.

Further details on assumptions used to estimate maintenance costs are given in Appendix A. Tables 11 and 14 of Appendix A provide itemized costs of the individual maintenance tasks for each of the scenarios.

Site 3—Large Commercial Development

Site 3 is a 10-acre commercial development consisting of a retail shopping center and parking lot. Figure 9 shows the layout of the site as planned for development, without stormwater control facilities to satisfy the minimum requirements. The site has 85 percent impervious cover. The topography of this site in its undeveloped condition causes drainage to flow from the upper left to the lower right (as shown in Figure 9); there are several defined drainage courses that are not classified as streams or sensitive areas. This site would be graded extensively to construct the large building and parking lot. Stormwater runon and through-flow in the drainage courses would occur unless diversions are provided. It is assumed that the site would be ringed with diversion trenches on the upslope sides to convey runon and through-flow around the site to the downstream conveyance system.

The costs of providing diversion trenches and constructing retaining walls or similarly effective slope stabilization measures near the site border are not included in this analysis because their necessity is an arbitrary result of the hypothetical site layout.

Site 3 Construction Stormwater Pollution Prevention Plan

For all new development and redevelopment projects that add or replace 2,000 square feet or more of impervious surface or clear more than 7,000 square feet, such as site 3, the manual requires preparation of a SWPPP to guide selection and implementation of a variety of BMPs during construction. The 12 minimum requirements for stormwater pollution prevention during construction are listed above for site 1. It is assumed that construction would take one year to complete, and that clearing and grading activities would continue through the wet season.

Several BMPs are necessary to control site runoff and erosion during the construction phase. A combination of intercepting swales, a temporary sediment pond, a stabilized construction entrance and equipment parking areas, mulch application to bare areas, stabilization of disturbed slopes, storm drain inlet protection on surrounding streets, and silt fencing would be used to control transport of sediments off the site and protect downstream properties and waterways during construction. Figure 10 shows the locations of the erosion and sediment control BMPs selected for the large commercial development site. It is assumed that the large commercial building would also require excavation that results in a relatively steep slope, where erosion control blankets are needed for soil stabilization. These BMPs would be in place prior to construction activities to satisfy the minimum requirements.

The BMPs are almost all the same for type A soils (suitable for infiltration) and type C soils (unsuitable for infiltration). The differences assumed for BMP applications with type A soils include reduced size of the temporary sediment pond, reduced extent of street sweeping, reduced

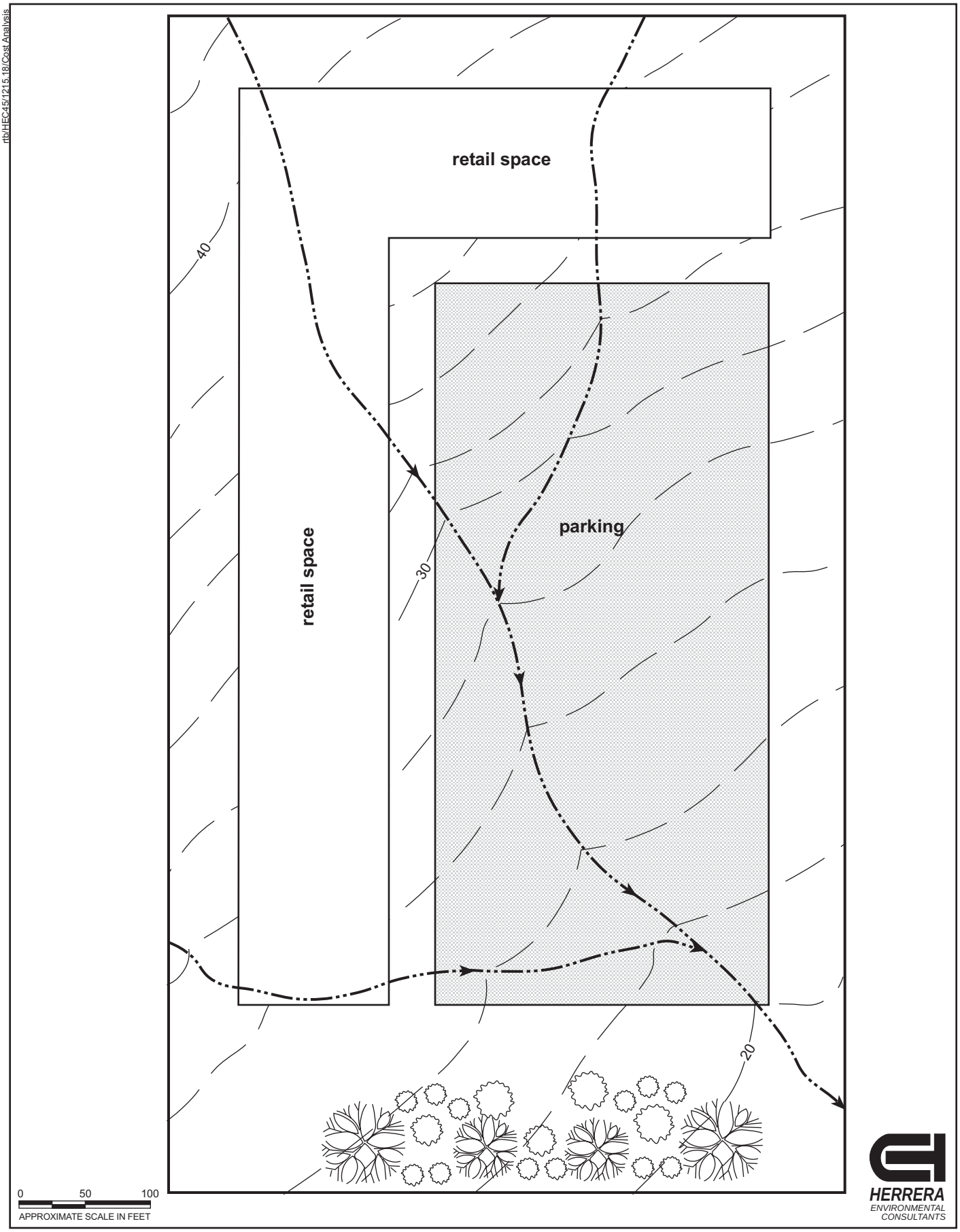

Figure 9. Ten-acre commercial development plan, without stormwater facilities, superimposed on natural (pre-development) topography and drainage features.

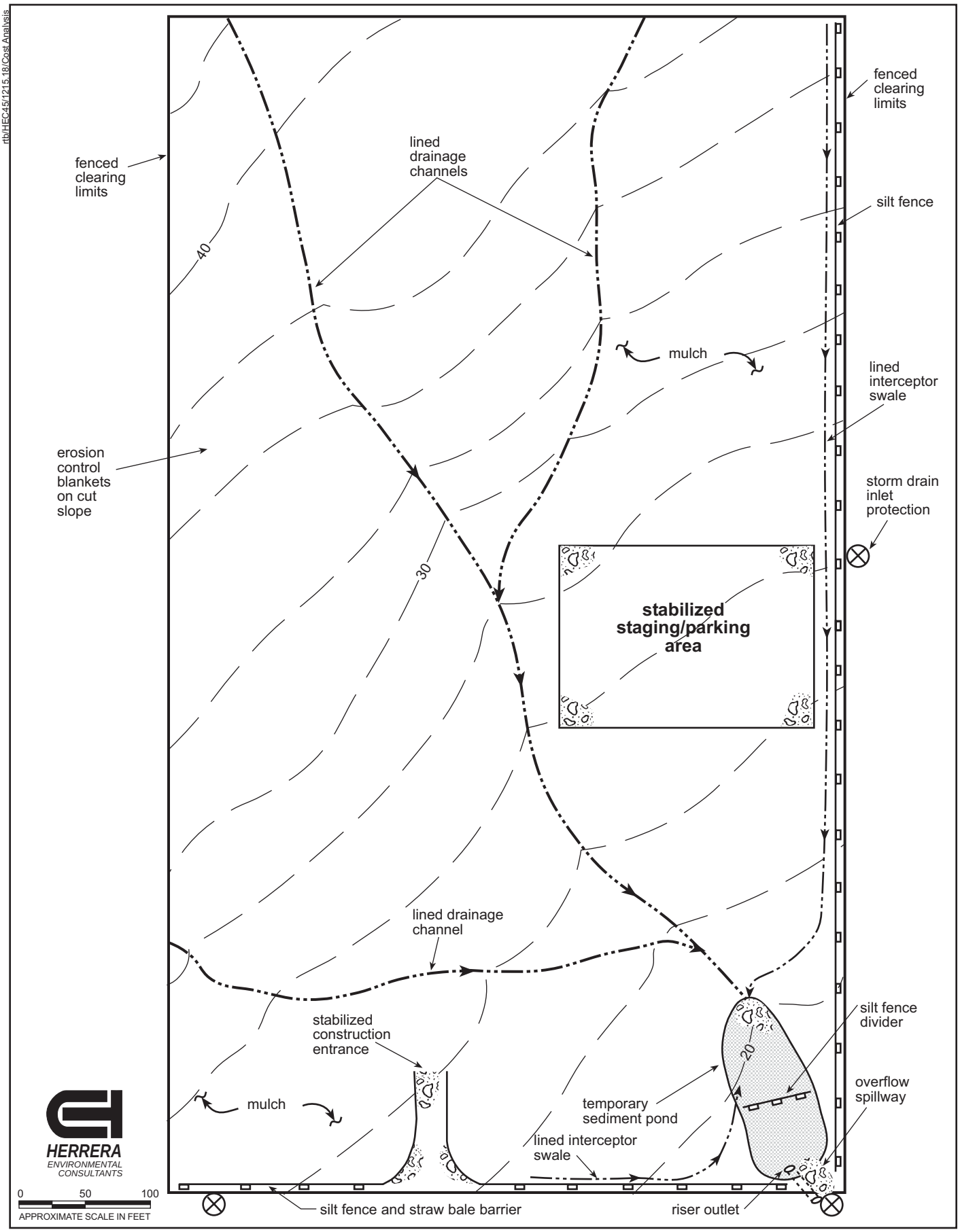

Figure 10. Erosion and sediment control BMPs for 10-acre commercial development.

extent of offsite catch basin cleaning, and elimination of a straw bale barrier along the lower left corner of the site as shown on Figure 10. Therefore, the cost estimate for the construction SWPPP associated with type A soils reflects slightly reduced BMP applications.

The intercepting swales would be used to convey site runoff to the sediment pond. These swales would be lined with suitable geotextiles or organic blankets, or stabilized with seed and mulch, to prevent erosion within the swale. Silt fencing would be used on downslope edges of the site boundary to prevent sediment discharge.

The manual specifies that sediment ponds be designed based on the 2-year, 24-hour storm peak runoff flow rate. The sediment pond size indicated on figure 10 is based on the 2-year peak runoff flow from the developed site with till soils (i.e., the larger sediment pond scenario for type C soils). Silt fencing would be used as a divider within the temporary sediment pond to enhance the removal of suspended sediments. The site entrance would be stabilized with quarry spalls, and all construction roads on the site and one main parking area would be stabilized with crushed rock. Mulch would be applied extensively to areas of exposed soil during staged construction. Silt fencing would be used to contain sediments on the site periphery that may be present in runoff that does not reach the interceptor swales. It is assumed that three catch basins on the adjacent street would require inlet protection. Other BMPs such as vehicle tire washing and spraying of dusty areas would be implemented during construction as needed.

Maintenance of the erosion and sediment control BMPs is a key component of the construction SWPPP. It is assumed that routine BMP maintenance checks would be performed once weekly and after runoff-producing storm events during the dry season, and daily during the wet season to ensure that BMPs continue to function effectively. Excess sediment accumulation must be removed from the pond and disposed of off the site or spread in a controlled location on the site. Silt fencing must be checked periodically, especially following storms, to determine if repairs or replacement fabric sections are needed. Mulch used to cover stripped site areas would be relocated and replaced as needed, as portions of the site are permanently stabilized. If sediment is tracked offsite onto neighboring streets, it must be swept and collected as necessary.

Costs for Construction Stormwater Pollution Prevention Plan

The construction cost for these SWPPP BMPs is estimated at approximately $54,000 for type A soils and $63,000 for type C soils. Tables 15 and 18 in Appendix A show itemized costs for the various BMP components and their associated construction procedures and materials. These costs do not include engineering planning and design fees, permit fees, performance bonding (or other appropriate financial instruments to ensure compliance with the approved SWPPP), and contingencies for unforeseen difficulties. Maintenance of the erosion control BMPs over the course of the 1-year construction period (included in the SWPPP BMP costs noted above) is estimated to cost approximately $10,000 for type A soils and $16,000 for type C soils (see Tables 17 and 21 in Appendix A, respectively). Appendix A provides further details on assumptions used to develop these costs.

Site 3 Permanent Stormwater Site Plan

The stormwater site plan must include provisions for maintaining natural drainage patterns, using source control BMPs to prevent pollutants from entering stormwater runoff, reducing hydrologic changes through onsite stormwater management techniques, treating runoff from smaller storm events, detaining runoff from larger storm events to prevent stream bank erosion due to high flows, and maintaining the BMPs that are chosen and implemented. Minimum requirement eight, pertaining to wetlands and minimum requirement nine, pertaining to basin planning, are assumed not to be applicable to this hypothetical site and this analysis.

In accordance with the manual, two preliminary considerations guided BMP selection for site 3. Oil control and special phosphorus control measures are not required for this site. The oil control requirement is assumed not applicable due to the traffic volume falling below the high use threshold. The standard western Washington peak flow control to match pre-development peak flow rates and durations is required because the site discharge is conveyed to a small stream (if site discharge is conveyed directly to a major water body, the standard does not apply).

Pollution Source Control BMPs

Pollution source control BMPs are important components of the stormwater site plan for this site to satisfy minimum requirement three. Several of the source control BMPs outlined in the manual are applicable to this development. The areas designated for garbage containers adjacent to the building should be covered or contained to prevent precipitation from contacting waste containers and to prevent the runoff from entering the nearby storm drainage system. The interior of this area must drain to the sanitary sewer if possible (BMP S1.50). Other materials and wastes that may introduce pollutants to stormwater should also be placed in the protected area. Cooking equipment such as vents and filters must not be cleaned outdoors unless a sanitary sewer drain is provided. In addition, storm drainage facilities must be maintained (BMP S2.00), and the parking lot should be swept frequently to collect and properly dispose of accumulated sediments and other materials that may contain pollutants (BMP S1.22).

Onsite Stormwater Management Measures

In addition to pollution source control BMPs, onsite stormwater management measures must also be implemented to infiltrate, disperse, and retain stormwater runoff onsite where practicable (minimum requirement five). Some examples of onsite stormwater management BMPs applicable to this commercial development include roof downspout infiltration, use of permeable/porous pavements in low traffic areas, and vegetated rooftops. For this site, the use of "typical" roof downspout infiltration trenches was assumed with infiltratable soils on site (type A). As with Site 2, the "alternative" infiltration design that is allowable in coarse soils was not assumed for this site because it is not likely that a grass strip would be provided between the building and the infiltration trenches in this type of development. Permanent stormwater facilities were sized, and the associated cost estimate developed, with roof downspout infiltration included. The contributing drainage area for the wetpond and infiltration basin is considerably reduced as a result (by approximately 25 percent).

For the scenario with type C soils, it was assumed that roof downspout dispersion systems would not be provided due to insufficient area for grass or other open space. The sizing of permanent stormwater treatment and flow control facilities accounted for all rooftop runoff because it was assumed that this runoff would reach the stormwater management pond quickly. Although it was assumed that porous pavements could be used for low traffic areas of the site, the sizing of the permanent stormwater treatment and flow control facilities conservatively assumed that all driveway and parking lot runoff would reach the pond quickly.

Permanent Stormwater Control Facilities by Soil Type

The permanent stormwater control facilities selected for the large commercial development site to satisfy the minimum requirements are dependent on soil type.

Type A Soils – With Infiltration

Infiltration is the preferred method of stormwater treatment and flow control, but infiltration requires suitable soils. For the scenario with type A soils, an infiltration basin preceded by a wetpond provides stormwater treatment. Figure 11 shows the layout of the site with the permanent stormwater control facilities for this condition. The infiltration basin would dispose of most runoff flows, but would have sufficient live storage capacity to detain and slowly release high flows to the nearby storm drainage system in this situation. Type A soils are suitable for infiltration disposal of runoff but are too porous to enable effective treatment of large volumes of water cost-effectively. Therefore, a wetpond (or other comparable treatment facility) is needed for pretreatment. The wetpond can also serve as a presettling facility to protect the infiltration soil surface from clogging.

The wetpond is designed to treat all runoff from the 6-month, 24-hour storm event and is divided into two separate cells. Both wetpond cells would be excavated approximately 4 feet deep, with an additional foot of depth in the first cell for sediment storage. The wetpond would overflow to the infiltration basin via a spillway. The infiltration basin would be excavated 4 feet below grade and is large enough to enable infiltration of most flow up to the 100-year event. An outlet control structure in the infiltration basin would enable limited flow to discharge to the nearby storm sewer system in extreme events, matching pre-developed site discharge rates and flow durations (the pre-developed site peak flows and volumes are very small in type A soils).

Type C Soils – Without Infiltration

For the scenario without infiltration, a combined wet/detention pond with a permanent pool provides water quality treatment and excess storage capacity for peak flow control, and a sand filter provides enhanced treatment. Two options were evaluated for this sand filter. One option considered placement of the sand filter in an underground concrete vault. It was assumed that relatively frequent maintenance access requirements for the sand filter would lead to selection of a rectangular concrete vault structure as opposed to a large diameter pipe structure with less head room in the interior. The other option considered placement of the sand filter bed in an open-air configuration with steep (1H:1V) side slopes surrounded by safety fencing. A maintenance access roadway to the bottom of the sand filter bed would be required with this option. The

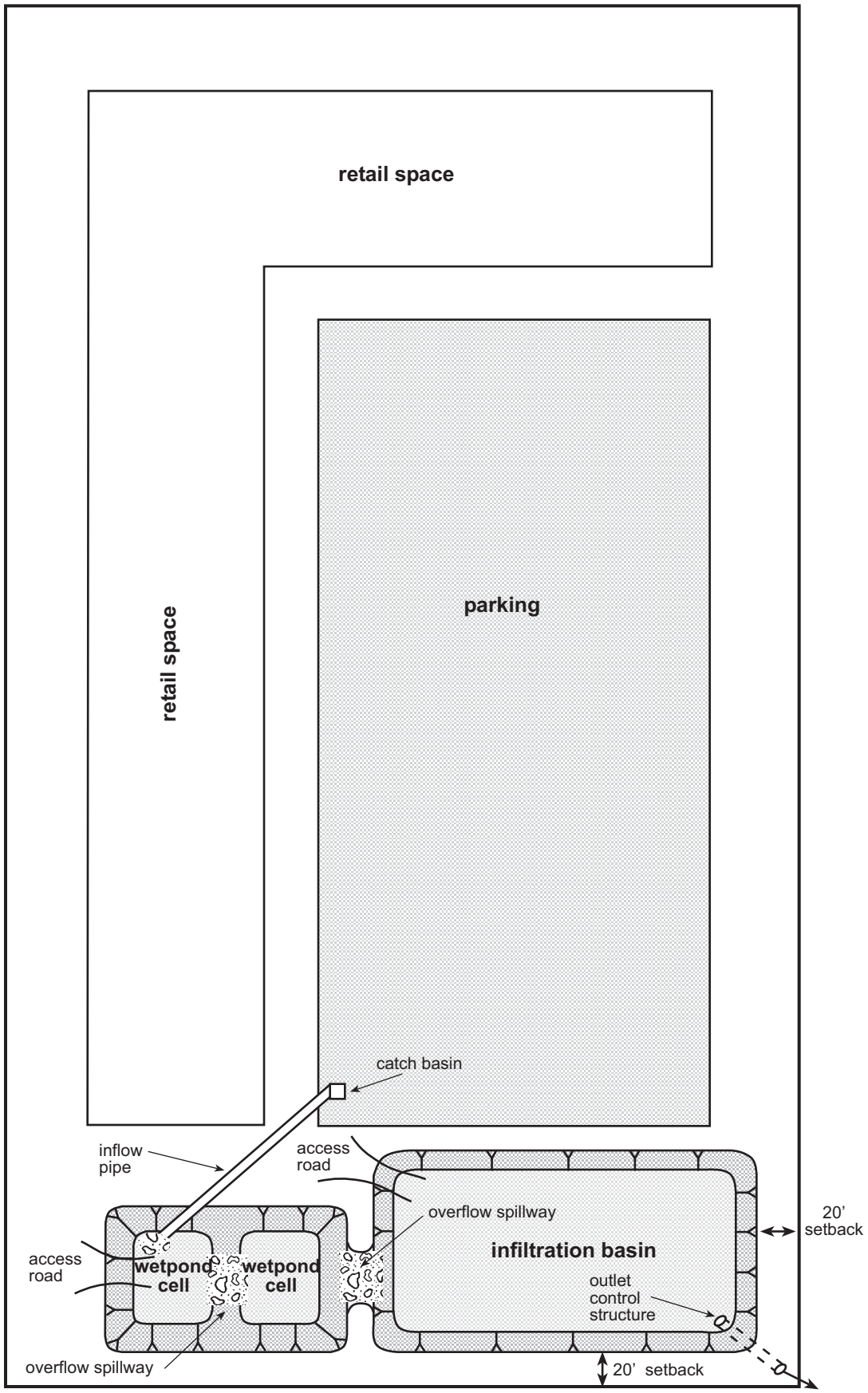

Figure 11. Permanent stormwater quality control BMPs for 10-acre commercial development with infiltration.

open-air configuration would reduce costs but would consume parking or roadway areas that may be valuable for the developer. Figure 12 shows the layout of the site with a combined wet/detention pond and the underground sand filter vault option. The treatment pool in the wet/detention pond and the subsequent sand filter constitute a two facility treatment train to perform the enhanced treatment that is required. The wetpond does not require special design features for enhanced phosphorus removal.

The wetpond has two cells separated by an earthen berm. The first cell is excavated approximately nine feet below existing grade, and the second cell is excavated eight feet below grade. Each cell provides four feet of water depth to create a permanent pool (during the wet months) for water quality treatment. The first cell has an additional foot of sediment storage capacity in the bottom. An additional 4 feet of storage space on top of the permanent pool provides detention capacity for the 100-year runoff event, including one foot of freeboard. This extra foot of storage allows for an emergency overflow spillway.

Because the detention storage volume needed is large in relation to the water quality treatment volume needed, the pond footprint area expands significantly in the upper detention zone. The pond has a multiple-orifice outflow restrictor above the permanent (treatment) pool level to maintain predevelopment site discharge rates. The detention outflow control structure directs flows into the sand filter. The bottom of the sand filter bed, whether in a vault or in an open-air configuration, is set approximately 8 feet below ground surface. The sand filter bed area was sized to treat the peak 2-year storm flow discharged from the detention outlet control structure, with a perforated pipe underdrain system to collect treated flows, and flows above the 2-year detained peak would be discharged directly to the nearby storm sewer system via an overflow pipe.

The permanent BMP facilities, both with infiltration and without infiltration, are located so that they receive runoff from the entire development and maintain the natural drainage pattern of the site. The excavation for the temporary sediment pond is expanded for the permanent stormwater control facilities. A catch basin is provided at the site discharge location; it is assumed that the catch basin outflow is piped into the storm drainage system adjacent to the site.

Site 3 Implementation Costs to Satisfy the Minimum Requirements

Costs With Infiltration

The total cost of planning, designing, and constructing the BMPs in the construction SWPPP and permanent stormwater site plan for the scenario with infiltration is estimated at approximately $320,000, including taxes and contingencies (see Table 16 in Appendix A). This total cost is higher than the cost estimated for the comparable 10-acre residential site. The size and cost of the wetpond and infiltration basin on site 3 would be significantly greater due to the greater amount of runoff generated on more impervious surfaces within the 10-acre development. The total cost for the scenario with the infiltration basin also includes the cost of performing a hydrogeologic evaluation to confirm infiltration suitability and/or determine the site-specific infiltration rate. The cost of the permanent stormwater facilities in the stormwater site plan is approximately 68 percent of the total implementation cost.

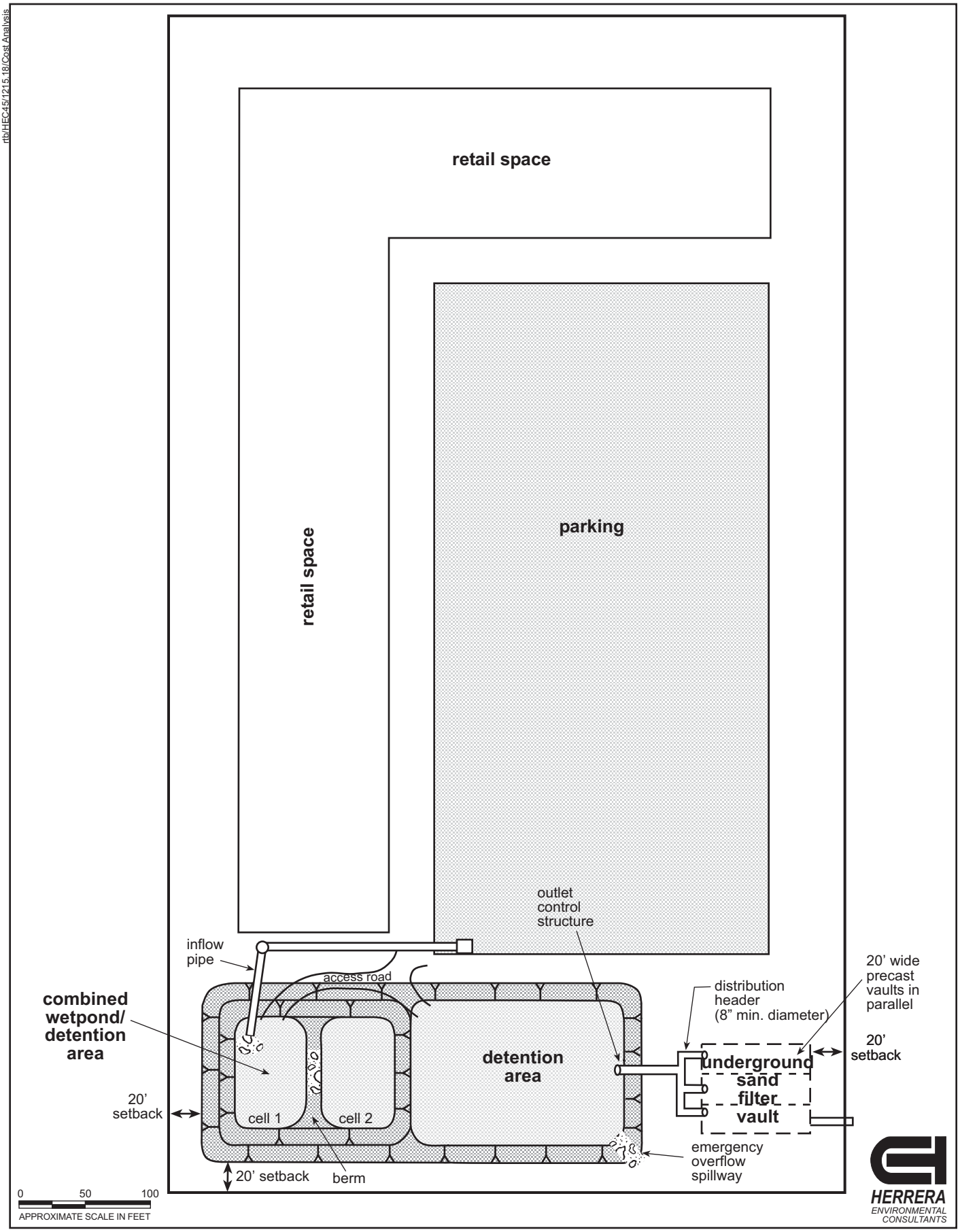

Figure 12. Permanent stormwater quality control BMPs for 10-acre commercial development without infiltration.

Costs Without Infiltration

The total cost of planning, designing, and constructing the BMPs in the construction SWPPP and permanent stormwater site plan for the scenario without infiltration and with the underground sand filter vault option is estimated at approximately $860,000. The cost for this scenario is high because of the large size of the sand filter vault, and the assumed use of precast concrete to create the sand filter vault. If large diameter pipe or other creative means were used to construct the underground sand filter, the cost could be reduced considerably. The cost of this same scenario with the open-air sand filter option is estimated at approximately $490,000. While the open-air sand filter would reduce costs by $370,000 compared to placement of the sand filter in a buried vault, it would mean that approximately 0.25 acres of parking lot is unavailable for other use. The cost of the permanent stormwater facilities in the stormwater site plan with the underground sand filter vault option in this scenario is approximately 88 percent of the total implementation cost. That percentage is reduced if the sand filter is placed in an open-air configuration.

Itemized costs for the components of the stormwater site plan are given for the three scenarios in Tables 16, 19, and 20 in Appendix A. Appendix A also provides further details on assumptions used to estimate costs.

Comparison of Treatment and Detention Storage Volumes to 1993 Estimates

For the scenario where infiltration is feasible in type A soils and a wetpond is used for treatment of the runoff prior to infiltration, the storage volumes in both the wetpond and the infiltration basin are now smaller in comparison to the sizes under the 1992 requirements. This is due to the requirement for onsite stormwater management (roof downspout infiltration). The volume of runoff assumed to reach the wetpond and infiltration basin is significantly less in comparison to the calculations associated with the 1992 requirements. The storage volumes in the wet/detention pond in type C soils analyzed in this case study are larger in size compared to the volumes estimated for this same site scenario in the 1993 report (Herrera 1993). This is because the wetpond treatment storage volume has increased as a result of the design criteria for the 6-month storm precipitation depth and the detention storage volume has increased considerably as a result of the requirement to match flow durations in addition to controlling peak flow rates.

The comparison of these storage volumes in type A soils is as follows:

- 1993 analysis (re-analyzed as discussed in Appendix C) -- wetpond treatment volume = 34,600 cubic feet; infiltration basin storage volume = 69,300 cubic feet

- Present analysis – wetpond treatment volume = 27,700 cubic feet; infiltration basin storage volume = 56,200 cubic feet

The comparison of these storage volumes in type C soils is as follows:

- 1993 analysis -- wetpond treatment volume = 35,600 cubic feet; detention storage volume = 69,400 cubic feet; total storage volume = 105,000 cubic feet

- Present analysis – wetpond treatment volume = 40,000 cubic feet; detention storage volume = 162,000 cubic feet; total storage volume = 202,000 cubic feet

The combination of greater storage volumes, the need for a sand filter to provide enhanced treatment, and potential placement of the sand filter underground results in much greater stormwater management costs in the present analysis compared to the 1993 analysis.

Site 3 Operation and Maintenance Requirements and Costs

Operation and Maintenance Assumptions

Routine maintenance of the permanent stormwater facilities includes such tasks as conducting annual inspections; mowing the grass in the infiltration basin and wetpond, or combined wet/detention pond, at least twice per year; removing accumulations of debris and floating materials once per year; removing accumulated sediments in the wetpond once the sediment storage depth in the bottom is full (assumed to be once every five years); tilling the infiltration basin soil or otherwise re-establishing maximum infiltration capacity as needed (assumed to be once every two years); raking the sand filtration surface once the depth of accumulated silt and debris on the surface exceeds ¼ inch (assumed to be once every two years); seeding of grassed areas that turn bare at least once per year; adding gravel to overflow spillways and access driveways as needed; replacing miscellaneous parts and materials as needed; and cleaning out connecting pipes. In addition, the large parking lot should be swept frequently to limit the amount of sediments that enter the permanent stormwater control facilities, enabling them to function more effectively. All catch basins and storm drains in the development should be cleaned frequently to prevent clogging and to remove some of the pollutants that otherwise could be flushed into the treatment and detention facilities during large storm events.

Operation and Maintenance Costs, With and Without Infiltration

The annual cost of routine maintenance procedures is estimated at approximately $6,400 for the scenario with the wetpond and infiltration/detention basin. The annual maintenance cost for the scenario with a combined wet/detention pond and sand filter (without infiltration) is estimated at approximately $6,200. Much of the annual operation and maintenance cost is associated with conveyance system cleaning and street sweeping as opposed to pond and vault maintenance.

Further details on assumptions used to estimate maintenance costs are provided in Appendix A. Tables 17 and 21 in Appendix A provide itemized costs of the individual maintenance tasks for each of the scenarios.

3. Summary of Stormwater Site Plan Costs

This section presents a summary of the estimated costs for the three hypothetical development sites. The stormwater site plan features that greatly affect the total cost of satisfying the minimum requirements for stormwater controls in new developments are discussed. This section presents comparisons to the cost estimates developed in 1993 for the same case study development examples, based upon the minimum requirements in the 1992 *Stormwater Management Manual for the Puget Sound Basin*. The intent of this comparison is to illustrate the differences in costs between the 1992 and the 2001 requirements. Land costs are not included in the present analysis because there is considerable variability in land costs across western Washington that unnecessarily complicates this comparison. While land costs are not included in this analysis, they are an extremely important variable to be considered in accommodating the stormwater management requirements. Many project sites, for example those along transportation corridors, impose constraints on the ability to provide stormwater management facilities within the available space and therefore additional land must be purchased for those facilities. In many of the urban areas of western Washington that land can be very expensive.

Design Issues Affecting Cost

The permanent stormwater facilities for the three hypothetical development sites are sized according to what appears to be reasonable for the site conditions, but without a detailed assessment to optimize costs. Specifically, the 1-acre commercial development example has all of its stormwater management facilities underground because ground surface area is typically valuable at these types of sites, whereas the stormwater management facilities are mostly aboveground at the residential and large-scale commercial sites. The surface area of aboveground pond facilities could be minimized through the use of retaining walls or other steep slope stabilization techniques. However, the conceptual designs of wetponds and infiltration basins produced for this analysis assumed enough space is available to allow for more gradual side slopes. Surface ponds ideally have very gradual side slopes that consume greater area, and this analysis assumed 3H:1V side slopes, the maximum (steepest) allowed by the manual, to minimize cost. These assumptions affect the amount of land devoted to stormwater control facilities, which in turn affects total implementation cost.

For underground facilities, the assumptions regarding depth of water in the vault have a direct influence on cost. For instance, if a sand filter vault is assumed to have two feet of ponding depth above the sand bed rather than four feet, then the area of the filter bed is larger, resulting in vault excavation and material costs that are greater in comparison to a deeper vault with a smaller footprint area.

As illustrated for the 10-acre commercial development example (site 3) and type C soils where infiltration is not possible, placement of the sand filter in an underground vault results in far greater cost than if the sand filter is placed in an open-air configuration. The tradeoff of

additional parking and driveway areas versus higher stormwater management costs on this site would constitute an important site planning decision.

Stormwater Control Components Having Greatest Cost Impact

The relatively expensive items in the construction SWPPP cost estimates are stabilization of construction site entrances, construction roads, equipment parking areas, and stripped areas on the sites with rock and mulch; excavation of temporary sediment ponds and interceptor swales; routine maintenance checks and upkeep of erosion and sediment control BMPs; and cleaning sediments off of streets adjacent to the sites. These BMPs are likely to be necessary on every developed site, so their cost cannot be avoided. The quarry spalls and crushed rock used for road stabilization may be used later in final site paving, so the cost of these materials cannot necessarily be categorized as strictly a construction SWPPP cost. The necessity of frequent street sweeping outside site entrances is uncertain and varies with site conditions.

The relatively expensive cost items for the permanent stormwater control BMPs are excavation of treatment and detention basins; liners for prevention of seepage in wetponds in porous type A soils (including topsoil backfill over the liner); inflow pipes, outflow pipes, and flow control structures; and downspout infiltration trenches. For the commercial site examples where it is assumed that some or all of the stormwater management facilities would be placed in underground vaults or tanks, the construction of those vaults and tanks is very expensive.

Additional costs that are not included in this analysis that may be incurred include compliance with local government requirements, such as fencing around permanent BMPs. Landscaping costs, which may be necessary to satisfy other local government requirements, may be reduced if the permanent BMPs can be incorporated into landscaping designs.

Total Stormwater Control Costs to Satisfy Minimum Requirements

The total estimated costs of compliance with the minimum requirements, not including land costs or foregone land use opportunity costs, are summarized on a per-acre basis in Table 1. A range of costs for each site is provided that incorporates the potential variation in soil condition, engineering planning and design costs, and construction costs. The range of costs per acre of site size are applicable only to the hypothetical sites discussed in this analysis. The cost to comply with the minimum requirements on other sites of various sizes and development plans can be estimated based on this information, with the understanding that each site has unique characteristics and development concerns that affect the actual cost of developing and implementing a stormwater site plan. Therefore, these cost figures should be considered only approximate indicators of the actual cost to be expected for a particular new residential or commercial development of comparable size. The costs listed in Table 1 include construction-phase SWPPP costs as well as permanent BMP costs.

Table 1. Summary of Costs to Comply with the Minimum Requirements for New Development

Type of Development	Low Cost Per Acre of Development	High Cost Per Acre of Development
10-acre single-family residential (5.5 dwelling units per acre)	$23,000	$24,000
1-acre commercial	$280,000	$570,000
10-acre commercial	$32,000	$86,000

Comparisons to Costs Associated With the Former Minimum Requirements

A similar cost analysis was performed for the 1992 *Stormwater Management Manual for the Puget Sound Basin*. Although the cost estimates for the current analysis include some items that were not incorporated in the 1993 analysis, those previous cost estimates provide a basis for a general evaluation of the effects of the updated stormwater management requirements on total implementation costs. The cost totals for the site examples with type C soils (i.e., no infiltration) in the 1993 report were updated to the year 2001 by using the same unit prices, as well as the same assumptions for engineering and permitting costs (30 percent) and taxes (8.8 percent), as applied in the present analysis. Thus, the 1993 cost analysis material quantities were used in combination with cost assumptions that parallel the present analysis as much as possible. Several minor cost items from the 1993 analysis were not incorporated in the cost tables for this report, and therefore a different approach was used to update those items to the year 2001. An adjustment factor of 30 percent was used to update these miscellaneous cost items, based on construction cost inflation observed in the Puget Sound area through the year 2000 and extrapolation to this year (ENR 2000).

The cost totals for the site examples with type B soils from the 1993 report were disregarded in the present analysis. Instead, new quantity and cost estimates were prepared for those site examples assuming type A soils, assuming the same types of permanent stormwater site plan BMPs as assumed in the present analysis, and incorporating the year 1992 design requirements to determine wetpond and infiltration basin sizes under the older requirements. The revised stormwater facility quantity estimates were then coupled with the year 2001 unit prices used for the present analysis to estimate comparable costs based on the previous design manual requirements. Appendix C presents a brief overview of the re-analysis performed for the 1993 cost examples with infiltration.

The updated cost totals for the 1993 examples, excluding land costs, are shown in Table 2 below in comparison to the cost totals from the present analysis.

This comparison illustrates some important points. If most or all of the site runoff can be infiltrated, and underground facilities are not needed in that process, the costs of managing stormwater are comparable or slightly lower in the present analysis. That is mostly due to the

effect that rooftop downspout infiltration has on reduction of wetpond and infiltration basin sizes.

Table 2. Comparison of Implementation Costs Under the Year 1992 and Year 2001 Stormwater Management Requirements.

Development Scenario	Total Implementation Costs Based on 1992 Standards	Total Implementation Costs Based on 2001 Standards	Difference in Cost
10-acre residential with infiltration	$280,000	$240,000	- 14%
10-acre residential without infiltration	$214,000	$230,000	+ 7%
1-acre commercial with infiltration	$84,000[a]	$280,000	+ 233%
1-acre commercial without infiltration	$41,000[a]	$570,000	+ 1290%
10-acre commercial with infiltration	$340,000	$320,000	- 6%
10-acre commercial without infiltration	$260,000	$490,000[b]	+ 88%

[a] The 1993 study assumed that the stormwater management facilities would be placed above ground rather than in vaults, and that greatly affects implementation cost.

[b] Cost associated with open-air sand filter rather than more expensive option with buried sand filter vault

The new requirements for enhanced treatment of runoff (sites 2 and 3) and flow control to match pre-developed flow durations as well as peak rates (for the scenarios with type C soils on all three sites) result in significantly greater storage volumes in the stormwater management ponds and vaults compared to the 1992 requirements. If a site cannot use an infiltration system for flow disposal, the cost of managing the stormwater rises significantly because of the required detention volume and the required enhanced treatment system (at non-residential sites). The detention storage volumes needed to satisfy the new flow duration control requirements, in particular, are much higher, on the order of twice the detention volumes previously needed for peak flow control only. In addition, the wetpool treatment storage volumes needed have increased slightly compared to the 1992 requirements because of a greater design storm precipitation depth. The increase in storage volumes needed on all of the example sites has a direct effect on compliance costs. When these facilities are placed in buried vaults, that cost increase becomes more pronounced.

The new requirements for onsite stormwater management using downspout infiltration systems and flow dispersion systems (among other techniques) also have an effect on overall costs. In the 10-acre residential development example with type A soils these facilities are relatively inexpensive due to the ability to use the "alternative" infiltration trench design. However, in the 1- and 10-acre commercial site examples with type A soils these systems are relatively expensive due to the need for inlet catch basins, perforated pipe, and soil backfill. Even with the greater relative cost for downspout infiltration at the commercial sites, the savings in cost that result from smaller pretreatment systems and infiltration systems (roughly 20 percent lower cost) is well worth the investment in downspout infiltration. In type C soils it was assumed that downspout infiltration systems would not be provided at any of the sites (inexpensive downspout dispersion systems were assumed), resulting in a greater volume of runoff flowing to the stormwater treatment and detention facilities. This analysis did not attempt to incorporate

creative design elements such as vegetated rooftops, porous pavements in selected areas, landscaping to promote infiltration and dispersion of runoff at the commercial sites, and other onsite runoff management techniques that can potentially result in significant cost savings due to smaller stormwater control ponds and vaults.

The overall trend that can be expected in stormwater management costs for sites where infiltration cannot be accomplished is a significant increase relative to the costs associated with satisfaction of the 1992 requirements. If infiltration can be accomplished, the overall stormwater management costs may be similar, and possibly lower, in comparison to the costs associated with the 1992 requirements. Some cost components, such as the costs for temporary erosion and sediment control, may not change significantly.

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APPENDIX A

Cost Estimates and Related Assumptions

Cost Estimate Assumptions and Itemized Cost Estimates

This appendix provides detailed information on assumptions and references used in developing the cost estimates for implementing stormwater site plans at the three hypothetical development sites described in Section 2. Itemized cost tabulations are included at the end of the appendix for all of the BMPs associated with the construction SWPPP and permanent stormwater site plan for the three sites.

Costs of equipment, labor, materials, engineering services, and permitting fees are included in the estimates. Unit prices are derived from estimates on other stormwater projects, from the *Site Work and Landscape Cost Data* guide (Means 2000), from the Washington State Department of Transportation's "unit bid analysis" information posted on their web site, and from educated estimates on items for which cost information is not published. An additional 10 percent is added to the subtotal construction cost to cover mobilization and demobilization of equipment for construction and maintenance of BMPs. A contingency of 25 percent is subsequently added to cover unforeseen difficulties during construction and other miscellaneous items. Contingencies are necessary in planning level engineering cost estimates; the 25 percent used here is typical for the limited amount of site information available. An additional cost is listed for investigation of soil suitability for infiltration in the scenarios where infiltration is used for stormwater treatment. Tax (at 8.8 percent) is included on the total construction costs. Engineering services and permitting fees are added at a rate of 30 percent on the total construction cost for most of the development scenarios to obtain the total BMP implementation cost for each site. The assumed percentage of cost for engineering and permitting services was reduced to 15 percent for the 10-acre commercial site with buried sand filter vault because the capital construction costs are disproportionately high due to underground facilities.

The total BMP implementation costs listed in Tables 2, 6, 10, 13, 16, 19, and 20 are relatively conservative estimates. However, site conditions may dictate higher costs if steep slopes and erosive soils are present, or if extensive landscaping is used to make the BMPs aesthetically pleasing. The total implementation cost could also be considerably lower for some sites of comparable size. The total cost estimates should be considered as indicative of approximate average implementation costs. All costs listed in this analysis are in 2001 dollars.

Assumptions Used to Estimate Construction Costs

Assumptions used in developing construction costs for procedures and materials common to all three hypothetical development sites and many BMPs are outlined below. Assumptions used in developing construction costs for procedures and materials unique to either construction SWPPP BMPs or permanent stormwater site plan BMPs are briefly outlined separately in subsequent sections of this appendix.

Construction SWPPP Assumptions

- The cost of excavation for all three sites and all stormwater facilities assumes a short hauling distance of 150 feet (implying onsite relocation and reuse of excavated material). Grading of excavated areas is also included in the unit price of excavation, as shown in the itemized cost tables. The unit price includes equipment and labor.

- The cost of seeding for bare areas assumes hydroseeding with a common utility mix and includes equipment and labor.

- The cost of straw mulch assumes it is mechanically blown on the site rather than hand-cast.

- The cost of street sweeping assumes it is done for one hour, once per week for 6 months adjacent to the 10-acre development sites with type A soils; three times per week adjacent to the 10-acre development sites with type C soils; five times during the course of construction at the 1-acre commercial development site with type A soils; and 10 times during the course of construction at the 1-acre commercial development site with type C soils.

- Approximately 10 percent of the total silt fence length would need to be repaired at the 10-acre development sites with type A soils, and approximately 20 percent of the total silt fence length would need to be repaired at the 10-acre development sites with type C soils.

Permanent Stormwater Site Plan Assumptions

- Bottom liners were assumed necessary for wetponds in type A soils. The unit cost of the bottom liners is based on recent experience with a variety of lining systems at the Cedar Hills Landfill and recent contractor bids for a stormwater pond liner at a park-and-ride site in Puyallup. The backfill over basin liners is assumed to be compacted topsoil or sand, 18 inches thick.

- Access driveways and maintenance pads for all pond-type BMPs were assumed to be 15 feet wide, and the driveway portion extending into the pond bottom was assumed to be common borrow soil underlying a crushed gravel surfacing.

- Pond-type BMPs were assumed to be hydroseeded upon completion of grading rather than via hand-spread seeding.

- For downspout infiltration systems at Site 1 (residential, type A soils), it was assumed that each house (48 total) would have all of its downspouts

draining into simple rock-filled trench systems without need for inlet catch basins and perforated pipe.

- It was assumed that the 1-acre commercial development building would have two separate downspout infiltration trench systems, and that the 10-acre commercial development building would have six separate trench systems. These systems would require inlet catch basins and perforated pipe. It was assumed that the catch basins used with these commercial downspout infiltration systems would be made of high density polyethylene rather than concrete to save on cost.

- Underground wet vaults were assumed to consist of 8-foot diameter corrugated steel pipe treated with asphalt coating.

- Underground infiltration tanks were assumed to consist of 5-foot diameter corrugated steel pipe with perforations in the bottom half of the barrel, laid on the drain rock.

- Underground detention systems were assumed to consist of 5-foot diameter corrugated aluminized steel pipe with prefabricated manifold connections, end caps and access risers.

- Underground sand filter vaults were assumed to consist of pre-cast concrete vault sections 20 feet in width, with lateral connecting pipes.

Operation and Maintenance Cost Assumptions

Operation and maintenance (O&M) costs are estimated for the temporary erosion and sediment control and permanent stormwater site plan BMPs. The total duration of construction for Sites 1 and 3 is assumed to be 12 months. The total duration of construction for Site 2 is assumed to be 2 months. The estimates of O&M costs for the construction SWPPPs are applicable only during the construction phase, that is, they are one-time costs. These O&M costs for construction SWPPP measures are factored into the total SWPPP costs listed in Tables 2, 6, 10, 13, 16, 19 and 20. The estimates of O&M costs for permanent stormwater control facilities are applicable as annual requirements. These O&M cost estimates are approximate. A contingency of 20 percent is added to all O&M cost estimates to account for miscellaneous maintenance requirements and variable site conditions. The following discussion details the assumptions used to develop the O&M cost estimates, which are found in Tables 3, 7, 8,11, 14, 17, and 21.

Erosion and Sediment Control BMP Maintenance

- It is assumed that erosion and sediment control BMPs are checked daily in the wet season, and once per week for the remainder of the year. In the

dry season it was assumed that several other checks would be needed following infrequent storm events.

- Sediment accumulations in temporary sediment ponds would be cleaned out once during construction on the 10-acre sites with type A soils, and twice during construction on the 10-acre sites with type C soils.

- Offsite catch basins adjacent to the site would be cleaned out for the 10-acre sites with type C soils, but such cleaning would not be needed on the 1-acre commercial site due to the short duration of construction, nor on the 10-acre sites with type A soils because offsite sediment transport would not be problematic in outwash soils.

- Laborers involved in all aspects of operation and maintenance of BMPs are paid at a rate of $30 per hour.

Permanent Stormwater Control BMP Maintenance

Permanent stormwater facilities must be routinely maintained on a scheduled basis for the life of the facilities. Assumptions used to develop O&M costs for permanent stormwater facilities are as follows:

- Infiltration and detention basins, which are normally dry, must be mowed twice per year to promote thick grass cover that enhances sediment settling and infiltration It is assumed that 4 hours of labor would be required to mow the infiltration basins at Sites 1 and 3, twice per year.

- The bottom and side slopes of infiltration basins and the bottoms of the infiltration tanks should be tilled periodically to loosen sediments that may clog the soil surface. It is assumed that tilling is conducted once every 2 years, requiring two laborers for one 8-hour work day on the 10-acre sites (Sites 1 and 3) and two laborers for 4 hours on the 1-acre site (Site 2). In addition to the labor cost, it is assumed that a lump cost of $300 covers mobilization, equipment, and sediment disposal (if necessary) associated with this activity.

- It is assumed that tilling, conditioning, and/or removal of sediment accumulations is conducted once every 2 years in the sand filters for Sites 2 and 3, requiring two laborers for 4 hours on the 1-acre site (Site 2) and two laborers for 8 hours on the 10-acre site (Site 3). In addition to the labor cost, it is assumed that a lump cost of $300 covers mobilization, equipment, and sediment disposal (if necessary) associated with this activity.

- It is assumed that sediment deposits are cleaned out once every 5 years in wetponds and wet vaults. The wetponds at Sites 1 and 3 take

approximately 16 hours to clean with a crew of two laborers, and the wet vault at Site 2 takes approximately 12 hours to clean with a crew of two laborers. It is assumed that mobilization, equipment, and sediment disposal associated with this activity costs $500 for Sites 1 and 3, and $300 for Site 2, in addition to the above labor costs.

- Catch basins and storm drains must also be cleaned out periodically to remove accumulated sediments and debris. It is assumed that some of the catch basins in the residential development are cleaned every year, that half of the catch basins in the parking lot at the 1-acre commercial site are cleaned once per year, and that roughly half of the catch basins in the parking lot for the 10-acre commercial site are cleaned each year. It is assumed that the cost is $200 per catch basin or storm drain segment.

- It is assumed that the catch basin inserts in each of four catch basins in the parking lot at Site 2 are replaced four times per year, for a total of 16 inserts per year.

- It is assumed that street or parking lot sweeping will be conducted at each of the sites. At the residential site (Site 1) it is assumed that a sweeper will operate 4 hours per month, for each of 7 months during the year. At the 1-acre commercial site (Site 2), it is assumed that a sweeper will operate 1 hour per month, for each of 7 months during the year. At the 10-acre commercial site (Site 3), it is assumed that a sweeper will operate 3 hours per month for a total of 7 months during the year.

Table 1. Cost estimate for construction stormwater pollution prevention plan -- 10-acre residential development with infiltration.

Item	Unit	Quantity	Unit Cost	Cost
Stabilized construction entrance - quarry spalls	CY	60	$35	$2,100
Stabilized construction entrance - geotextile	SY	170	$1.25	$213
Stabilized staging/parking area - crushed gravel	CY	700	$20	$14,000
Tire wash	LS	1	$500	$500
Interceptor swale excavation	CY	90	$15	$1,350
Interceptor swale seeding	AC	0.6	$1,000	$600
Interceptor swale bonded fiber matrix	AC	0.6	$200	$120
Check dams - quarry spalls	CY	10	$35	$350
Dewatering bag	EA	1	$300	$300
Storm drain inlet protection	EA	2	$200	$400
Straw mulch	AC	9	$800	$7,200
Silt fence	LF	340	$5	$1,700
Water spray for dust control	LS	1	$300	$300
Temporary sediment pond excavation	CY	160	$10	$1,600
Quarry spalls for spillway, inlet dissipation	CY	7	$35	$245
Compacted earth fill berm	CY	55	$4	$220
8" CMP riser pipe for outflow (incl. conc. base)	EA	1	$400	$400
Corrugated polyethylene dewatering device	EA	1	$200	$200
Subtotal				$31,800
Maintenance of erosion and sediment control BMPs (see Table 3 for details)				$8,400
Total SWPPP cost				$ 40,200

Table 2. Cost estimate for permanent stormwater site plan -- 10-acre residential development with infiltration.

Item	Unit	Quantity	Unit Cost	Cost
Onsite stormwater management measures				
Downspout infiltration trench excavation	CY	430	$10	$4,300
Downspout infiltration trench drain rock	CY	320	$30	$9,600
Geotextile for material separation	SY	1,600	$1.25	$2,000
Wet pond				
Excavation	CY	1,300	$10	$13,000
Bottom liner	SY	720	$10	$7,200
Liner backfill (soil or sand)	CY	270	$15	$4,050
Common borrow and gravel for access driveways	CY	40	$20	$800
Outflow structure (catch basin with debris barrier)	EA	1	$3,000	$3,000
Discharge pipe, 12" diam.	LF	50	$40	$2,000
Infiltration basin				
Hydrogeologic evaluation for soil suitability	LS	1	$10,000	$10,000
Basin excavation	CY	2,600	$10	$26,000
Basin liner - nonwoven geotextile	SY	1,870	$1.25	$2,338
Quarry spalls for overflow spillway	CY	7	$35	$245
Seeding	AC	0.39	$1,000	$390
Gravel for access driveway, maintenance pad	CY	41	$20	$820
Observation wells	EA	2	$200	$400
Subtotal				$86,100
Construction SWPPP cost (see Table 1 for detailed TESC costs)				$40,200
Subtotal construction cost				$126,300
Mobilization and demobilization (10%)				$12,630
Subtotal stormwater control BMP cost				$138,930
Contingencies (25%)				$34,733
Total construction cost				$173,700
Taxes (8.8%)				$15,300
Engineering and permitting fees for stormwater facilities (30%) (excluding basic site drainage infrastructure)				$52,100
Total cost for stormwater BMP construction				$240,000

Table 3. Cost estimate for stormwater BMP operation and maintenance -- 10-acre residential development with infiltration.

Item	Unit	Quantity	Unit Cost	Cost
Construction SWPPP BMPs				
Regular maintenance checks on BMPs	EA	190	$20	$3,800
Clean out sediment buildup in pond	EA	1	$300	$300
Repair damaged sections of silt fencing	LF	30	$5	$150
Sediment removal in offsite catch basins	EA	0	$200	$0
Street sweeping	HR	26	$100	$2,600
Removal of BMPs at conclusion of construction	LS	1	$1,500	$1,500
Total SWPPP O&M cost (for 1 year only)				$8,400
Permanent stormwater site plan BMPs				
Annual inspection	EA	1	$100	$100
Misc. cleanup	EA	1	$50	$50
Drain and remove sediments from wetpond	EA	0.2	$1,460	$292
Mow infiltration basin	EA	2	$120	$240
Till/remove sediments from infiltration basin	EA	0.5	$780	$390
Spot seeding/repair of bare areas	LS	1	$100	$100
Clean catch basins and storm drains	EA	10	$200	$2,000
Street sweeping	HR	28	$100	$2,800
Subtotal permanent stormwater BMP annual O&M cost				$6,000
Contingencies (20%)				$1,200
Total annual O&M cost				$7,200

Table 4. Cost estimate for construction stormwater pollution prevention plan -- 10-acre residential development without infiltration and without wet season shutdown

Item	Unit	Quantity	Unit Cost	Cost
Stabilized construction entrance - quarry spalls	CY	60	$35	$2,100
Stabilized construction entrance - geotextile	SY	170	$1.25	$213
Stabilized staging/parking area - crushed gravel	CY	700	$20	$14,000
Tire wash	LS	1	$500	$500
Interceptor swale excavation	CY	90	$15	$1,350
Interceptor swale seeding	AC	0.6	$1,000	$600
Interceptor swale bonded fiber matrix	AC	0.6	$200	$120
Check dams - quarry spalls	CY	10	$35	$350
Dewatering bag	EA	1	$300	$300
Storm drain inlet protection	EA	8	$200	$1,600
Straw mulch	AC	9	$800	$7,200
Silt fence	LF	340	$5	$1,700
Water spray for dust control	LS	1	$300	$300
Temporary sediment pond excavation	CY	290	$10	$2,900
Quarry spalls for spillway, inlet dissipation	CY	7	$35	$245
Compacted earth fill berm	CY	65	$4	$260
8" CMP riser pipe for outflow (incl. conc. base)	EA	1	$400	$400
Corrugated polyethylene dewatering device	EA	1	$200	$200
Subtotal				$34,300
Maintenance of erosion and sediment control BMPs (see Table 7 for details)				$14,500
Total SWPPP cost				$48,800

Table 5. Cost estimate for construction stormwater pollution prevention plan -- 10-acre residential development without infiltration and with wet season shutdown

Item	Unit	Quantity	Unit Cost	Cost
Stabilized construction entrance - quarry spalls	CY	60	$35	$2,100
Stabilized construction entrance - geotextile	SY	170	$1.25	$213
Stabilized staging/parking area - crushed gravel	CY	700	$20	$14,000
Tire wash	LS	1	$500	$500
Interceptor swale excavation	CY	90	$15	$1,350
Interceptor swale seeding	AC	0.6	$1,000	$600
Interceptor swale bonded fiber matrix	AC	0.6	$200	$120
Check dams - quarry spalls	CY	10	$35	$350
Dewatering bag	EA	1	$300	$300
Storm drain inlet protection	EA	4	$200	$800
Straw mulch	AC	5	$800	$4,000
Soil stabilization with polyacrylamide for winter	AC	9	$200	$1,800
Silt fence	LF	340	$5	$1,700
Water spray for dust control	LS	1	$500	$500
Temporary sediment pond excavation	CY	290	$10	$2,900
Quarry spalls for spillway, inlet dissipation	CY	7	$35	$245
Compacted earth fill berm	CY	65	$4	$260
8" CMP riser pipe for outflow (incl. conc. base)	EA	1	$400	$400
Corrugated polyethylene dewatering device	EA	1	$200	$200
Subtotal				$32,300
Maintenance of erosion and sediment control BMPs (see Table 8 for details)				$9,100
Total SWPPP cost				$41,400

Table 6. Cost estimate for permanent stormwater site plan -- 10-acre residential development without infiltration.

Item	Unit	Quantity	Unit Cost	Cost
Onsite stormwater management measures				
Downspout dispersion splash blocks	EA	96	$20	$1,920
Wet/detention pond				
Excavation	CY	6,200	$10	$62,000
Common borrow and gravel for access driveways	CY	65	$20	$1,300
Quarry spalls for inlet dissipation, overflow spillway	CY	7	$35	$245
Seeding	AC	0.45	$1,000	$450
Outlet piping	LF	60	$40	$2,400
Outlet control structure	EA	1	$3,500	$3,500
Subtotal				$71,800
Construction SWPPP cost (see Table 4 for detailed TESC costs)				$48,800
Subtotal construction cost				$120,600
Mobilization and demobilization (10%)				$12,100
Subtotal stormwater control BMP cost				$132,700
Contingencies (25%)				$33,200
Total construction cost				$165,900
Taxes (8.8%)				$14,600
Engineering and permitting fees for stormwater facilities (30%) (excluding basic site drainage infrastructure)				$49,800
Total cost for stormwater BMP construction				$230,000

Table 7. Cost estimate for stormwater BMP operation and maintenance -- 10-acre residential development without infiltration and without wet season shutdown.

Item	Unit	Quantity	Unit Cost	Cost
Construction SWPPP BMPs				
Regular maintenance checks on BMPs	EA	190	$20	$3,800
Clean out sediment buildup in pond	EA	2	$300	$600
Repair damaged sections of silt fencing	LF	70	$5	$350
Sediment removal in offsite catch basins	EA	2	$200	$400
Street sweeping	HR	78	$100	$7,800
Removal of BMPs at conclusion of construction	LS	1	$1,500	$1,500
Total SWPPP O&M cost (for 1 year only)				$14,500
Permanent stormwater site plan BMPs				
Annual inspection	EA	1	$100	$100
Misc. cleanup	EA	1	$50	$50
Drain and remove sediments from wet pond	EA	0.2	$1,460	$292
Mow wet/detention pond slopes	EA	2	$120	$240
Spot seeding/repair of bare areas	LS	1	$50	$50
Clean catch basins and storm drains	EA	20	$200	$4,000
Street sweeping	HR	28	$100	$2,800
Subtotal permanent stormwater BMP annual O&M cost				$7,500
Contingencies (20%)				$1,500
Total annual O&M cost				$9,000

Table 8. Cost estimate for stormwater BMP operation and maintenance -- 10-acre residential development without infiltration and with wet season shutdown.

Item	Unit	Quantity	Unit Cost	Cost
Construction SWPPP BMPs				
Regular maintenance checks on BMPs	EA	60	$20	$1,200
Clean out sediment buildup in pond	EA	2	$300	$600
Repair damaged sections of silt fencing	LF	70	$5	$350
Sediment removal in offsite catch basins	EA	1	$200	$200
Street sweeping	HR	52	$100	$5,200
Removal of BMPs at conclusion of construction	LS	1	$1,500	$1,500
Total SWPPP O&M cost (for 1 year only)				$9,100
Permanent stormwater site plan BMPs				
Annual inspection	EA	1	$100	$100
Misc. cleanup	EA	1	$50	$50
Drain and remove sediments from wet pond	EA	0.2	$1,460	$292
Mow wet/detention pond slopes	EA	2	$120	$240
Spot seeding/repair of bare areas	LS	1	$50	$50
Clean catch basins and storm drains	EA	20	$200	$4,000
Street sweeping	HR	28	$100	$2,800
Subtotal permanent stormwater BMP annual O&M cost				$7,500
Contingencies (20%)				$1,500
Total annual O&M cost				$9,000

Table 9. Cost estimate for construction stormwater pollution prevention plan -- 1-acre commercial development with infiltration.

Item	Unit	Quantity	Unit Cost	Cost
Stabilized construction entrance - quarry spalls	CY	60	$35	$2,100
Stabilized construction entrance - geotextile	SY	170	$1.25	$213
Storm drain inlet protection	EA	2	$200	$400
Straw mulch	AC	0.8	$800	$640
Silt fence	LF	390	$5	$1,950
Temporary sediment pond excavation	CY	17	$10	$170
Quarry spalls for spillway, inlet dissipation	CY	2	$35	$70
Rock and washed gravel spillway	CY	2	$40	$80
Subtotal				$5,600
Maintenance of erosion and sediment control BMPs (see Table 11 for details)				$1,300
Total SWPPP cost				$6,900

Table 10. Cost estimate for permanent stormwater site plan -- 1-acre commercial development with infiltration.

Item	Unit	Quantity	Unit Cost	Cost
Onsite stormwater management measures				
Downspout infiltration trench excavation	CY	40	$10	$400
Downspout infiltration trench drain rock	CY	30	$30	$900
Compacted backfill	CY	10	$4	$40
Geotextile for material separation	SY	200	$1.25	$250
Type 1 catch basin with sump	EA	2	$400	$800
4" perforated drain pipe	LF	250	$2	$500
Extension of downspouts into trenches	LF	25	$2	$50
Wet vaults				
Excavation	CY	540	$15	$8,100
Vault structures (8' diameter steel pipe)	LF	110	$95	$10,450
Vault installation and connections	LF	110	$80	$8,800
Pipe bedding gravel	CY	100	$20	$2,000
Vault backfill	CY	235	$4	$940
Hauling and disposal of excess material	CY	305	$20	$6,100
Discharge pipe, 12" diam.	LF	40	$40	$1,600
Infiltration tanks				
Hydrogeologic evaluation for soil suitability	LS	1	$10,000	$10,000
Tank excavation	CY	1,000	$15	$15,000
Tank structures (5' diameter perforated steel pipe)	LF	405	$80	$32,400
Tank installation and connections	LF	405	$50	$20,250
Pipe bedding gravel	CY	260	$20	$5,200
Tank backfill	CY	460	$4	$1,840
Hauling and disposal of excess material	CY	540	$20	$10,800
Observation wells	EA	4	$200	$800
Catch basin inserts	EA	4	$100	$400
Subtotal				$137,600
Construction SWPPP cost (see Table 9 for detailed TESC costs)				$6,900
Subtotal construction cost				$144,500
Mobilization and demobilization (10%)				$14,450
Subtotal stormwater control BMP cost				$158,950
Contingencies (25%)				$39,700
Total construction cost				$198,700
Taxes (8.8%)				$17,500
Engineering and permitting fees for stormwater facilities (30%) (excluding basic site drainage infrastructure)				$59,600
Total cost for stormwater BMP construction				$280,000

Table 11. Cost estimate for stormwater BMP operation and maintenance -- 1-acre commercial development with infiltration.

Item	Unit	Quantity	Unit Cost	Cost
Construction SWPPP BMPs				
Regular maintenance checks on BMPs	EA	10	$20	$200
Water spray for dust suppression	LS	1	$100	$100
Repair damaged sections of silt fencing	LF	20	$5	$100
Street sweeping	HR	5	$100	$500
Removal of BMPs at conclusion of construction	LS	1	$400	$400
Total SWPPP O&M cost (for 2 months only)				$1,300
Permanent stormwater site plan BMPs				
Annual inspection	EA	1	$100	$100
Misc. cleanup	EA	1	$50	$50
Drain and remove sediments from wet vault	EA	0.2	$1,020	$204
Till/remove sediments from infiltration tanks	EA	0.5	$540	$270
Replace catch basin inserts	EA	16	$100	$1,600
Clean catch basins and storm drains	EA	2	$200	$400
Parking lot sweeping	HR	7	$100	$700
Subtotal permanent stormwater BMP annual O&M cost				$3,300
Contingencies (20%)				$700
Total annual O&M cost				$4,000

Table 12. Cost estimate for construction stormwater pollution prevention plan -- 1-acre commercial development without infiltration.

Item	Unit	Quantity	Unit Cost	Cost
Stabilized construction entrance - quarry spalls	CY	60	$35	$2,100
Stabilized construction entrance - geotextile	SY	170	$1.25	$213
Interceptor swale excavation	CY	36	$15	$540
Interceptor swale geosynthetic liner	SY	144	$2	$288
Check dams - quarry spalls	CY	2	$35	$70
Storm drain inlet protection	EA	2	$200	$400
Straw mulch	AC	0.8	$800	$640
Silt fence	LF	390	$5	$1,950
Temporary sediment pond excavation	CY	31	$10	$310
Quarry spalls for spillway, inlet dissipation	CY	2	$35	$70
Rock and washed gravel spillway	CY	2	$40	$80
Subtotal				$6,700
Maintenance of erosion and sediment control BMPs (see Table 14 for details)				$1,900
Total SWPPP cost				$8,600

Table 13. Cost estimate for permanent stormwater site plan -- 1-acre commercial development without infiltration.

Item	Unit	Quantity	Unit Cost	Cost
Wet vaults				
Excavation	CY	690	$15	$10,350
Vault structures (8' diameter steel pipe)	LF	140	$95	$13,300
Vault installation and connections	LF	140	$80	$11,200
Pipe bedding gravel	CY	130	$20	$2,600
Vault backfill	CY	300	$4	$1,200
Hauling and disposal of excess material	CY	390	$20	$7,800
Discharge pipe, 12" diam.	LF	40	$40	$1,600
Detention vaults				
Excavation	CY	2,400	$15	$36,000
Vault structures (5' diameter steel pipe)	LF	970	$75	$72,750
Vault installation and connections	LF	970	$50	$48,500
Pipe bedding gravel	CY	600	$20	$12,000
Vault backfill	CY	1,100	$4	$4,400
Hauling and disposal of excess material	CY	1,300	$20	$26,000
Discharge pipe, 12" diam.	LF	100	$40	$4,000
Outlet control structure	EA	1	$3,500	$3,500
Sand filter vault				
Excavation	CY	250	$15	$3,750
Vault structure (20' wide precast sections)	LF	25	$750	$18,750
Vault installation, connections, and backfill	LF	25	$350	$8,750
Sand	CY	40	$25	$1,000
Perforated pipe underdrains	LF	50	$2	$100
Drain rock	CY	20	$30	$600
Geotextile fabric for material separation	SY	60	$1.25	$75
Catch basin inserts	EA	4	$100	$400
Subtotal				$ 288,600
Construction SWPPP cost (see Table 12 for detailed TESC costs)				$8,600
Subtotal construction cost				$297,200
Mobilization and demobilization (10%)				$29,700
Subtotal stormwater control BMP cost				$326,900
Contingencies (25%)				$81,700
Total construction cost				$408,600
Taxes (8.8%)				$36,000
Engineering and permitting fees for stormwater facilities (30%) (excluding basic site drainage infrastructure)				$122,600
Total cost for stormwater BMP construction				$570,000

Table 14. Cost estimate for stormwater BMP operation and maintenance -- 1-acre commercial development without infiltration.

Item	Unit	Quantity	Unit Cost	Cost
Construction SWPPP BMPs				
Regular maintenance checks on BMPs	EA	10	$20	$200
Water spray for dust suppression	LS	1	$100	$100
Repair damaged sections of silt fencing	LF	20	$5	$100
Street sweeping	HR	10	$100	$1,000
Removal of BMPs at conclusion of construction	LS	1	$500	$500
Total SWPPP O&M cost (for 2 months only)				$1,900
Permanent stormwater site plan BMPs				
Annual inspection	EA	1	$100	$100
Misc. cleanup	EA	1	$50	$50
Drain and remove sediments from wet vault	EA	0.2	$1,020	$204
Till surface of sand filter / replace sand	EA	0.5	$540	$270
Replace catch basin inserts	EA	16	$100	$1,600
Clean catch basins and storm drains	EA	2	$200	$400
Parking lot sweeping	HR	7	$100	$700
Subtotal permanent stormwater BMP annual O&M cost				$3,300
Contingencies (20%)				$700
Total annual O&M cost				$4,000

Table 15. Cost estimate for construction stormwater pollution prevention plan -- 10-acre commercial development with infiltration.

Item	Unit	Quantity	Unit Cost	Cost
Stabilized construction entrance - quarry spalls	CY	60	$35	$2,100
Stabilized construction entrance - geotextile	SY	170	$1.25	$213
Stabilized staging/parking area - crushed gravel	CY	500	$20	$10,000
Interceptor swale excavation	CY	150	$15	$2,250
Interceptor swale seeding	AC	0.14	$1,000	$140
Interceptor swale bonded fiber matrix	AC	0.14	$200	$28
Check dams - quarry spalls	CY	20	$35	$700
Storm drain inlet protection	EA	3	$200	$600
Straw mulch	AC	9	$800	$7,200
Silt fence	LF	1300	$5	$6,500
Erosion control blankets	SY	2200	$5	$11,000
Temporary sediment pond excavation	CY	220	$10	$2,200
Quarry spalls for spillway, inlet dissipation	CY	7	$35	$245
Compacted earth fill berm	CY	100	$4	$400
8" CMP riser pipe for outflow (incl. conc. base)	EA	1	$400	$400
Corrugated polyethylene dewatering device	EA	1	$200	$200
Subtotal				$44,200
Maintenance of erosion and sediment control BMPs (see Table 17 for details)				$10,000
Total SWPPP cost				$54,200

Table 16. Cost estimate for permanent stormwater site plan -- 10-acre commercial development with infiltration.

Item	Unit	Quantity	Unit Cost	Cost
Onsite stormwater management measures				
Downspout infiltration trench excavation	CY	230	$10	$2,300
Downspout infiltration trench drain rock	CY	170	$30	$5,100
Compacted backfill	CY	60	$4	$240
Geotextile for material separation	SY	1,170	$1.25	$1,463
Type 1 catch basin with sump	EA	6	$800	$4,800
4" perforated drain pipe	LF	1,500	$2	$3,000
Extension of downspouts into trenches	LF	100	$2	$200
Wet pond				
Excavation	CY	1,350	$10	$13,500
Bottom liner	SY	1,160	$10	$11,600
Soil or sand backfill on bottom liner	CY	580	$15	$8,700
Common borrow and gravel for access driveways	CY	35	$20	$700
Outflow structure (catch basin with debris barrier)	EA	1	$3,000	$3,000
Discharge pipe, 12" diam.	LF	200	$40	$8,000
Infiltration basin				
Hydrogeologic evaluation for soil suitability	LS	1	$10,000	$10,000
Basin excavation	CY	3,400	$10	$34,000
Compacted earthen berm	CY	30	$4	$120
Basin liner - nonwoven geotextile	SY	2,600	$1.25	$3,250
Quarry spalls for overflow spillway	CY	35	$35	$1,225
Seeding	AC	0.57	$1,000	$570
Gravel for access driveway, maintenance pad	CY	35	$20	$700
Observation wells	EA	3	$200	$600
Subtotal				$113,100
Construction SWPPP cost (see Table 15 for detailed TESC costs)				$54,200
Subtotal construction cost				$167,300
Mobilization and demobilization (10%)				$16,730
Subtotal stormwater control BMP cost				$184,030
Contingencies (25%)				$46,000
Total construction cost				$230,000
Taxes (8.8%)				$20,200
Engineering and permitting fees for stormwater facilities (30%) (excluding basic site drainage infrastructure)				$69,000
Total cost for stormwater BMP construction				$320,000

Table 17. Cost estimate for stormwater BMP operation and maintenance -- 10-acre commercial development with infiltration.

Item	Unit	Quantity	Unit Cost	Cost
Construction SWPPP BMPs				
Regular maintenance checks on BMPs	EA	190	$20	$3,800
Water spray for dust suppression	LS	1	$500	$500
Clean out sediment buildup in pond	EA	1	$300	$300
Repair damaged sections of silt fencing	LF	130	$5	$650
Sediment removal in offsite catch basins	EA	3	$200	$600
Street sweeping	HR	26	$100	$2,600
Removal of BMPs at conclusion of construction	LS	1	$1,500	$1,500
Total SWPPP O&M cost (for 1 year only)				$10,000
Permanent stormwater site plan BMPs				
Annual inspection	EA	1	$100	$100
Misc. cleanup	EA	1	$50	$50
Drain and remove sediments from wet pond	EA	0.2	$1,460	$292
Mow infiltration basin	EA	2	$120	$240
Till/remove sediments from infiltration basin	EA	0.5	$780	$390
Spot seeding/repair of bare areas	LS	1	$100	$100
Clean catch basins and storm drains	EA	10	$200	$2,000
Parking lot sweeping	HR	21	$100	$2,100
Subtotal permanent stormwater BMP annual O&M cost				$5,300
Contingencies (20%)				$1,100
Total annual O&M cost				$6,400

Table 18. Cost estimate for construction stormwater pollution prevention plan -- 10-acre commercial development without infiltration.

Item	Unit	Quantity	Unit Cost	Cost
Stabilized construction entrance - quarry spalls	CY	60	$35	$2,100
Stabilized construction entrance - geotextile	SY	170	$1.25	$213
Stabilized staging/parking area - crushed gravel	CY	500	$20	$10,000
Interceptor swale excavation	CY	150	$15	$2,250
Interceptor swale seeding	AC	0.14	$1,000	$140
Interceptor swale bonded fiber matrix	AC	0.14	$200	$28
Check dams - quarry spalls	CY	20	$35	$700
Storm drain inlet protection	EA	3	$200	$600
Straw mulch	AC	9	$800	$7,200
Silt fence	LF	1300	$5	$6,500
Straw bale barrier	LF	160	$5	$800
Erosion control blankets	SY	2200	$5	$11,000
Temporary sediment pond excavation	CY	400	$10	$4,000
Quarry spalls for spillway, inlet dissipation	CY	7	$35	$245
Compacted earth fill berm	CY	100	$4	$400
8" CMP riser pipe for outflow (incl. conc. base)	EA	1	$400	$400
Corrugated polyethylene dewatering device	EA	1	$200	$200
Subtotal				$46,800
Maintenance of erosion and sediment control BMPs (see Table 21 for details)				$16,100
Total SWPPP cost				$62,900

Table 19. Cost estimate for permanent stormwater site plan -- 10-acre commercial development without infiltration and with buried sand filter.

Item	Unit	Quantity	Unit Cost	Cost
Wet/detention pond				
Excavation	CY	10,400	$10	$104,000
Common borrow and gravel for access driveways	CY	125	$20	$2,500
Quarry spalls for inlet dissipation, overflow spillway	CY	35	$35	$1,225
Seeding	AC	1.33	$1,000	$1,330
Outlet piping	LF	300	$40	$12,000
Outlet control structure	EA	1	$3,500	$3,500
Sand filter vault				
Excavation	CY	2,450	$15	$36,750
Shoring	SY	400	$10	$4,000
Vault structure (20' wide precast sections)	LF	240	$750	$180,000
Vault construction/installation	LF	240	$350	$84,000
Sand	CY	260	$25	$6,500
Perforated pipe underdrains	LF	240	$2	$480
Drain rock	CY	175	$30	$5,250
Geotextile fabric for material separation	SY	520	$1.25	$650
Subtotal				$442,200
Construction SWPPP cost (see Table 18 for detailed TESC costs)				$62,900
Subtotal construction cost				$505,100
Mobilization and demobilization (10%)				$50,500
Subtotal stormwater control BMP cost				$555,600
Contingencies (25%)				$138,900
Total construction cost				$694,500
Taxes (8.8%)				$61,100
Engineering and permitting fees for stormwater facilities (15%) (excluding basic site drainage infrastructure)				$104,180
Total cost for stormwater BMP construction				$860,000

Table 20. Cost estimate for permanent stormwater site plan -- 10-acre commercial development without infiltration and with open air sand filter.

Item	Unit	Quantity	Unit Cost	Cost
Wet/detention pond				
Excavation	CY	10,400	$10	$104,000
Common borrow and gravel for access driveways	CY	125	$20	$2,500
Quarry spalls for inlet dissipation, overflow spillway	CY	35	$35	$1,225
Seeding	AC	1.33	$1,000	$1,330
Outlet piping	LF	300	$40	$12,000
Outlet control structure	EA	1	$3,500	$3,500
Sand filter				
Excavation	CY	3,050	$15	$45,750
Drain rock	CY	170	$30	$5,100
Sand	CY	260	$25	$6,500
Access driveway crushed gravel surfacing	CY	40	$20	$800
Access driveway containment wall blocks	LS	1	$5,000	$5,000
Perforated pipe underdrains	LF	240	$2	$480
Geotextile fabric for material separation	SY	520	$1.25	$650
Seeding on side slopes	LS	1	$400	$400
Perimeter fencing	LF	410	$15	$6,150
Subtotal				$195,400
Construction SWPPP cost (see Table 21 for detailed TESC costs)				$62,900
Subtotal construction cost				$258,300
Mobilization and demobilization (10%)				$25,800
Subtotal stormwater control BMP cost				$284,100
Contingencies (25%)				$71,000
Total construction cost				$355,100
Taxes (8.8%)				$31,200
Engineering and permitting fees for stormwater facilities (30%) (excluding basic site drainage infrastructure)				$106,530
Total cost for stormwater BMP construction				$490,000

Table 21. Cost estimate for stormwater BMP operation and maintenance -- 10-acre commercial development without infiltration.

Item	Unit	Quantity	Unit Cost	Cost
Construction SWPPP BMPs				
Regular maintenance checks on BMPs	EA	190	$20	$3,800
Water spray for dust suppression	LS	1	$500	$500
Clean out sediment buildup in pond	EA	2	$300	$600
Repair damaged sections of silt fencing	LF	260	$5	$1,300
Sediment removal in offsite catch basins	EA	3	$200	$600
Street sweeping	HR	78	$100	$7,800
Removal of BMPs at conclusion of construction	LS	1	$1,500	$1,500
Total SWPPP O&M cost (for 1 year only)				$16,100
Permanent stormwater site plan BMPs				
Annual inspection	EA	1	$100	$100
Misc. cleanup	EA	1	$50	$50
Drain and remove sediments from wet pond	EA	0.2	$1,460	$292
Mow wet/detention pond slopes	EA	2	$120	$240
Spot seeding/repair of bare areas	LS	1	$50	$50
Till surface of sand filter / replace sand	LS	0.5	$780	$390
Clean catch basins and storm drains	EA	10	$200	$2,000
Parking lot sweeping	HR	21	$100	$2,100
Subtotal permanent stormwater BMP annual O&M cost				$5,200
Contingencies (20%)				$1,000
Total annual O&M cost				$6,200

APPENDIX B

Technical Assumptions Used in Analysis of Stormwater Best Management Practices

Technical Assumptions Used in Analysis of Stormwater Best Management Practices

The technical assumptions, runoff modeling methods, and design parameters used in the analysis of stormwater BMPs for each of the three hypothetical development sites are outlined below.

Two methods were used to estimate runoff from the sites and size stormwater facilities. StormShed, which employs the Santa Barbara Urban Hydrograph (SBUH) method, was used to determine water quality treatment volumes for permanent pretreatment and water quality treatment ponds. The King County Run Time Series (KCRTS) model was used to estimate runoff peak flows for pre- and post-developed conditions, and to determine the size of stormwater detention facilities. KCRTS is a continuous simulation model that functions similarly to the Ecology Hydrologic Model, which, when released, will be WSDOE's preferred tool for stormwater analysis. The water quality sand filtration systems were sized based on treatment of the post-detention 2-year peak flow derived with KCRTS.

Rainfall data used in StormShed for analyzing stormwater runoff volumes are from SeaTac Airport (estimated from isopluvial maps). The 6-month, 24-hour precipitation depth was used to calculate water quality treatment volume, and was estimated to be 1.44 inches, or 72 percent of the 2-year precipitation depth at SeaTac Airport (2.0 inches). The cost analyses for these same site examples for the 1992 storm water manual requirements (Herrera 1993) assumed 1.28 inches for the 6-month storm depth.

The SCS curve numbers (CN) used in the StormShed runoff modeling are:

- Type A soil, residential site, pervious areas in the post-development condition CN = 80 ("good" grass cover)
- Type A soil, commercial sites, pervious areas in the post-development condition CN = 85 ("fair" grass cover)
- Type C soil, residential site, pervious areas in the post-development condition CN = 86 ("good" grass cover)
- Type C soil, commercial sites, pervious areas in the post-development condition CN = 90 ("fair" grass cover)
- Impervious surfaces on all sites CN = 98.

Curve number values listed above for Type A soils are slightly conservative. This resulted in more conservative runoff volume estimates for water quality treatment, pretreatment and infiltration pond designs.

The infiltration rate assumed for the sites with suitable soils is 1 inch per hour.

Depth to ground water is assumed to be 20 feet (below the bottom of an infiltration basin) for all sites.

Rainfall data from the SeaTac rain gauge was used in the KCRTS runoff modeling with a 1.0 scaling factor. The predevelopment ground cover for all of the sites is assumed to be 100 percent forest.

The land use categories and areas used in the KCRTS runoff modeling are:

- Type A soil, 10-acre residential site, predeveloped condition – 10-acres outwash forest.
- Type A soil, 1-acre commercial site, predeveloped condition – 1-acre outwash forest.
- Type A soil, 10-acre commercial site, predeveloped condition – 10-acres outwash forest.
- Type A soil, 10-acre residential site, during construction – 90 percent (9.0 acres) outwash grass, 10 percent (1.0 acre) impervious
- Type A soil, 10-acre residential site, developed condition with on-site storm water management BMPs – 3.3–acres drain to downspout infiltration systems, 2.1-acres impervious, 4.6-acres outwash grass.
- Type A soil, 1-acre commercial site, developed condition with on-site storm water management BMPs – 0.2-acres drain to downspout infiltration systems, 0.1-acres outwash grass, 0.7-acres impervious.
- Type A soil, 10-acre commercial site, developed condition with on-site storm water management BMPs – 2.5-acres drain to downspout infiltration systems, 6.0-acres impervious, 1.5-acres outwash grass.
- Type C soil, 10-acre residential site, predeveloped condition – 10-acres till forest.
- Type C soil, 1-acre commercial site, predeveloped condition – 1-acre till forest.
- Type C soil, 10-acre commercial site, predeveloped condition – 10-acres till forest.

- Type C soil, 10-acre residential site, during construction – 90 percent (9.0 acres) till grass, 10 percent (1.0 acre) impervious

- Type C soil, 10-acre residential site, developed condition – 1.65-acres till grass (rooftops to downspout dispersion), 1.65-acres rooftop impervious, 2.1-acres other impervious, 4.6-acres till grass (lawns).

- Type C soil, 1-acre commercial site, developed condition – 0.9-acres impervious, 0.1-acres till grass.

- Type C soil, 10-acre commercial site, developed condition – 8.5-acres impervious, 1.5-acres till grass.

APPENDIX C

Re-Analysis of 1993 Cost Examples with Infiltration Systems

Re-Analysis of 1993 Cost Examples with Infiltration Systems

This appendix provides information on the methods and results of a re-analysis of stormwater management costs for the site examples from the 1993 cost analysis report (Herrera 1993) that included runoff infiltration. That report assumed type B soils for the infiltration scenarios, whereas the present report assumes type A soils for the infiltration scenarios. To make the cost estimates as comparable as possible, the soil type must be consistent. Therefore, a decision was made to re-analyze the 1993 infiltration examples assuming type A soils. The 1992 design requirements set forth in the *Stormwater Management Manual for the Puget Sound Basin* (Ecology 1992) were applied to the three case study sites with type A soils.

This re-analysis essentially maintains consistency with all aspects of the 2001 cost analysis examples for type A soils, except the sizing of the treatment and flow control facilities is based on the 1992 requirements. The 1993 cost analysis examples for type C soils were not included in this re-analysis, as there was no need to revise the sizes and types of stormwater facilities for those examples to enable a fair cost comparison. The methods used to adjust the cost estimates for those examples to year 2001 dollars are described in the main body of this report.

Permanent Stormwater Site Plan Assumptions

It was assumed that a wetpond and infiltration basin would be used in combination to accomplish treatment and flow disposal at each of the three case study sites for the scenario with type A soils. As discussed in the present report, type A soils enable disposal of large quantities of runoff but pretreatment must be provided. The 1992 Ecology manual required full 6-month design storm treatment prior to discharge to an infiltration system using one of several options, among them a wetpond. Wetponds were assumed for all three sites to closely match the assumptions used in the 2001 cost analysis examples.

As was done in the 1993 report, it was assumed that the stormwater control facilities for the 1-acre commercial development site (Site 2) would be placed aboveground. Likewise, the wetpond and infiltration basin for each of the 10-acre site examples were assumed to be aboveground. The wetponds were sized based on the runoff volume associated with 64 percent of the 2-year 24-hour storm rainfall depth.

The infiltration basins were sized to infiltrate all site runoff up to the 100-year event, with drawdown criteria as stipulated in the 1992 manual (these criteria have not changed in the 2001 manual). The native soil infiltration rate for each of these examples was assumed to be 4 inches per hour, which is on the low end of what is typically observed in type A soils. The 1992 manual required application of a factor of safety of 2, and therefore the design infiltration rate applied in this re-analysis was 2 inches per hour for each infiltration basin. As described in Appendix B, the 2001 analyses of the infiltration examples assumed a design infiltration rate of 1 inch per

hour, incorporating a factor of safety of 4 (as if the native soil infiltration rate were measured as 4 inches per hour).

Whereas the 2001 case study examples assumed that rooftop runoff would be disposed of via infiltration trenches, the re-analysis of the 1993 infiltration examples assumed that rooftop runoff would reach the wetponds and infiltration basins.

Results of the Re-analysis of Costs for Sites with Infiltration Capacity Under the 1992 Requirements

Tables C-1 through C-9 present the cost estimates for the permanent stormwater control facilities, temporary erosion and sediment control facilities, and operations and maintenance of temporary and permanent facilities for each of the three case studies in type A soils. These cost tables incorporate unit prices, contingencies, taxes, and engineering and permitting fees that are consistent with the tables for the 2001 cost analysis examples (see Tables 1 through 21 in Appendix A). Thus, the cost estimates presented in Tables C-1 through C-9 are in year 2001 dollars.

Table C-1. Cost estimate for permanent stormwater quality control facilities -- 10-acre residential development with infiltration (1992 design standards).

Item	Unit	Quantity	Unit Cost	Cost
Wet pond				
Excavation	CY	2,000	$10	$20,000
Bottom liner	SY	1,400	$10	$14,000
Liner backfill (soil or sand)	CY	470	$15	$7,050
Common borrow and gravel for access driveways	CY	40	$20	$800
Outflow structure (catch basin with debris barrier)	EA	1	$3,000	$3,000
Discharge pipe, 12" diam.	LF	50	$40	$2,000
Infiltration basin				
Hydrogeologic evaluation for soil suitability	LS	1	$10,000	$10,000
Basin excavation	CY	3,400	$10	$34,000
Basin liner - nonwoven geotextile	SY	2,150	$1.25	$2,688
Quarry spalls for overflow spillway	CY	7	$35	$245
Seeding	AC	0.44	$1,000	$440
Gravel for access driveway, maintenance pad	CY	41	$20	$820
Observation wells	EA	2	$200	$400
Subtotal				$95,400
ESC plan cost (see Table C-2 for detailed ESC costs)				$46,810
Subtotal construction cost				$142,210
Mobilization and demobilization (10%)				$14,221
Subtotal stormwater control BMP cost				$156,431
Contingencies (25%)				$39,108
Total construction cost				$195,540
Soils investigation for infiltration suitability (cost range $6,200 to $7,900)				$6,200
Taxes (8.8%)				$17,750
Additional engineering and permitting fees (30%)				$58,660
Total cost for stormwater BMP implementation (see Table C-3 for annual operation and maintenance costs)				$280,000

Table C-2. Cost estimate for erosion and sediment control measures -- 10-acre residential development with infiltration (1992 design standards).

Item	Unit	Quantity	Unit Cost	Cost
Stabilized construction roads and entrances				
4"-8" quarry spalls	CY	90	$35.00	$3,150
2"-4" crushed rock	CY	790	$20.00	$15,800
Interceptor swales				
Excavation	CY	450	$15.00	$6,750
Temporary seeding	AC	0.29	$1,000.00	$290
Check dams (pea gravel filled sandbags)	CY	1	$35.00	$35
Sediment trap				
Excavation	CY	300	$10.00	$3,000
2"-4" gravel fill for outflow weir	CY	6.5	$35.00	$228
3/4"-1.5" gravel fill for outflow weir	CY	15	$35.00	$525
4" gravel outflow protection	CY	5	$35.00	$175
Filter fabric fencing	LF	30	$5.00	$150
Sediment pond				
Excavation	CY	340	$10.00	$3,400
2"-4" gravel fill for inlet protection	CY	2	$35.00	$70
Compacted earth fill berm	CY	80	$4.00	$320
12" riser pipe for outflow (incl. conc. base)	EA	1	$400.00	$400
2" perforated drain pipe on bottom	LF	25	$1.00	$25
0.5" gravel backfill for drain pipe	CY	0.5	$30.00	$15
Filter fabric wrapping around drain pipe	SY	8	$1.25	$10
12" outflow pipe	LF	45	$10.00	$450
4" gravel outflow protection	CY	11	$35.00	$385
Filter fabric fencing	LF	50	$5.00	$250
Miscellaneous				
Mulch for bare site areas	AC	2	$800.00	$1,600
4" gravel protection for offsite diversion	CY	2	$35.00	$70
Removal of sediment BMPs	LS	1	$1,500.00	$1,500
Subtotal				$38,598
Maintenance of erosion and sediment control BMPs (see Table C-3 for details)				$8,210
Total ESC plan cost				$46,810

Table C-3. Cost estimate for stormwater BMP annual operation and maintenance -- 10-acre residential development with infiltration (1992 design standards).

Item	Unit	Quantity	Unit Cost	Cost
Erosion and sediment control plan BMPs				
Regular maintenance checks on BMPs (2/week)	EA	104	$20.00	$2,080
Rotate mulch cover on areas exposed	AC	2	$800.00	$1,600
Clean out sediment buildup in traps and ponds	EA	6	$60.00	$360
Repair damaged sections of filter fabric fencing	LF	40	$5.00	$200
Collect and dispose of sediments tracked offsite	LS	1	$2,600.00	$2,600
Subtotal erosion and sediment control BMP maintenance cost				$6,840
Contingencies (20%)				$1,368
Total ESC O&M cost (for 1 year only)				$8,210
Permanent stormwater quality control BMPs				
Mow infiltration, presettling, and detention basins	EA	2	$120.00	$240
Rake infiltration and presettling basins	EA	0.5	$780.00	$390
Clean out sediment buildup in presettling basin	EA	1	$225.00	$225
Periodically replace materials and equipment	LS	1	$250.00	$250
Clean catch basins and storm drains	EA	10	$200.00	$2,000
Street sweeping	LS	1	$2,800.00	$2,800
			subtotal	*$1,105*
Subtotal permanent stormwater control annual O&M cost				$5,905
Contingencies (20%)				$1,181
Total annual O&M cost				$7,090

Table C-4. Cost estimate for permanent stormwater quality control facilities -- 1-acre commercial development with infiltration (1992 design standards).

Item	Unit	Quantity	Unit Cost	Cost
Wet pond				
Excavation	CY	450	$10	$4,500
Bottom liner	SY	380	$10	$3,800
Liner backfill (soil or sand)	CY	130	$15	$1,950
Common borrow and gravel for access driveway	CY	20	$20	$400
Outflow structure (catch basin with debris barrie	EA	1	$3,000	$3,000
Discharge pipe, 12" diam.	LF	50	$40	$2,000
Infiltration basin				
Hydrogeologic evaluation for soil suitability	LS	1	$10,000	$10,000
Basin excavation	CY	580	$10	$5,800
Basin liner - nonwoven geotextile	SY	250	$1.25	$313
Quarry spalls for overflow spillway	CY	7	$35	$245
Seeding	AC	0.10	$1,000	$100
Gravel for access driveway, maintenance pad	CY	20	$20	$400
Observation wells	EA	2	$200	$400
Subtotal				$32,900
ESC plan cost (see Table C-5 for detailed ESC costs)				$9,020
Subtotal construction cost				$41,920
Mobilization and demobilization (10%)				$4,192
Subtotal stormwater control BMP cost				$46,112
Contingencies (25%)				$11,528
Total construction cost				$57,640
Soils investigation for infiltration suitability (cost range $3,300 to $4,500)				$3,300
Taxes (8.8%)				$5,360
Additional engineering and permitting fees (30%)				$17,290
Total cost for stormwater BMP implementation (see Table C-6 for annual operation and maintenance costs)				$84,000

Table C-5. Cost estimate for erosion and sediment control measures -- 1-acre commercial development with infiltration (1992 design standards).

Item	Unit	Quantity	Unit Cost	Cost
Stabilized construction roads and entrances				
4"-8" quarry spalls	CY	50	$35.00	$1,750
2"-4" crushed rock	CY	50	$20.00	$1,000
Interceptor swales				
Excavation	CY	105	$15.00	$1,575
Temporary seeding	AC	0.07	$1,000.00	$70
Sediment trap				
Excavation	CY	115	$10.00	$1,150
2"-4" gravel fill for outflow weir	CY	4	$35.00	$140
3/4"-1.5" gravel fill for outflow weir	CY	10	$35.00	$350
Baffles (4'x8'x1/2" plywood, 6' posts 8' o.c.)	LS	1	$270.00	$270
4" gravel outflow protection	CY	5	$35.00	$175
Filter fabric fencing	LF	20	$5.00	$100
Miscellaneous				
Mulch for bare site areas	AC	0.4	$800.00	$320
Removal of sediment BMPs	LS	1	$400.00	$400
Subtotal				$7,300
Maintenance of erosion and sediment control BMPs (see Table C-6 for details)				$1,720
Total ESC plan cost				$9,020

Table C-6. Cost estimate for stormwater BMP annual operation and maintenance -- 1-acre commercial development with infiltration (1992 design standards).

Item	Unit	Quantity	Unit Cost	Cost
Erosion and sediment control plan BMPs				
Regular maintenance checks on BMPs (2/week)	EA	18	$20.00	$360
Rotate mulch cover on areas exposed	AC	0.5	$800.00	$400
Clean out sediment buildup in traps and ponds	EA	2	$60.00	$120
Repair damaged sections of filter fabric fencing	LF	10	$5.00	$50
Collect and dispose of sediments tracked offsite	LS	1	$500.00	$500
Subtotal erosion and sediment control BMP maintenance cost				$1,430
Contingencies (20%)				$286
Total ESC O&M cost (for 1 year only)				$1,720
Permanent stormwater quality control BMPs				
Mow infiltration, presettling, and detention basins	EA	2	$60.00	$120
Rake infiltration and presettling basins	EA	0.5	$400.00	$200
Clean out sediment buildup in presettling basin	EA	1	$100.00	$100
Periodically replace materials and equipment	LS	1	$150.00	$150
Clean catch basin	EA	2	$200.00	$400
Parking lot sweeping	LS	1	$700.00	$700
			subtotal	*$570*
Subtotal permanent stormwater control annual O&M cost				$1,670
Contingencies (20%)				$334
Total annual O&M cost				$2,000

Table C-7. Cost estimate for permanent stormwater quality control facilities -- 10-acre commercial development with infiltration (1992 design standards).

Item	Unit	Quantity	Unit Cost	Cost
Wet pond				
Excavation	CY	2,700	$10	$27,000
Bottom liner	SY	1,740	$10	$17,400
Soil or sand backfill on bottom liner	CY	580	$15	$8,700
Common borrow and gravel for access driveways	CY	41	$20	$820
Outflow structure (catch basin with debris barrier)	EA	1	$3,000	$3,000
Discharge pipe, 12" diam.	LF	50	$40	$2,000
Infiltration basin				
Hydrogeologic evaluation for soil suitability	LS	1	$10,000	$10,000
Basin excavation	CY	4,050	$10	$40,500
Basin liner - nonwoven geotextile	SY	2,540	$1.25	$3,175
Quarry spalls for overflow spillway	CY	7	$35	$245
Seeding	AC	0.51	$1,000	$510
Gravel for access driveway, maintenance pad	CY	41	$20	$820
Observation wells	EA	3	$200	$600
Subtotal				$114,800
ESC plan cost (see Table C-8 for detailed ESC costs)				$57,450
Subtotal construction cost				$172,250
Mobilization and demobilization (10%)				$17,225
Subtotal stormwater control BMP cost				$189,475
Contingencies (25%)				$47,369
Total construction cost				$236,840
Soils investigation for infiltration suitability (cost range $6,800 to $8,500)				$6,800
Taxes (8.8%)				$21,440
Additional engineering and permitting fees (30%)				$71,050
Total cost for stormwater BMP implementation (see Table C-9 for annual operation and maintenance costs)				$340,000

Table C-8. Cost estimate for erosion and sediment control measures -- 10-acre commercial development with infiltration (1992 design standards).

Item	Unit	Quantity	Unit Cost	Cost
Stabilized construction roads and entrances				
4"-8" quarry spalls	CY	180	$35.00	$6,300
2"-4" crushed rock	CY	900	$20.00	$18,000
Interceptor swales				
Excavation	CY	830	$15.00	$12,450
Temporary seeding	AC	0.55	$1,000.00	$550
Check dams (pea gravel filled sandbags)	CY	4.2	$35.00	$147
Sediment pond				
Excavation	CY	350	$10.00	$3,500
2"-4" gravel fill for inlet protection	CY	3	$35.00	$105
Compacted earth fill berm	CY	575	$4.00	$2,300
Baffles (4'x8'x1/2" plywood, 6' posts 8' o.c.)	LS	1	$360.00	$360
12" riser pipe for outflow (incl. conc. base)	EA	1	$400.00	$400
2" perforated drain pipe on bottom	LF	35	$1.00	$35
0.5" gravel backfill for drain pipe	CY	0.6	$30.00	$18
Filter fabric wrapping around drain pipe	SY	11	$1.25	$14
12" outflow pipe	LF	45	$10.00	$450
4" gravel outflow protection	CY	11	$35.00	$385
Filter fabric fencing	LF	50	$5.00	$250
Miscellaneous				
Mulch for bare site areas	AC	2	$800.00	$1,600
4" gravel protection for offsite diversions	CY	7	$35.00	$245
Removal of sediment BMPs	LS	1	$1,500.00	$1,500
Subtotal				$48,609
Maintenance of erosion and sediment control BMPs (see Table C-9 for details)				$8,840
Total ESC plan cost				$57,450

Table C-9. Cost estimate for stormwater BMP annual operation and maintenance -- 10-acre commercial development with infiltration (1992 design standards).

Item	Unit	Quantity	Unit Cost	Cost
Erosion and sediment control plan BMPs				
Regular maintenance checks on BMPs (2/week)	EA	104	$20.00	$2,080
Rotate mulch cover on areas exposed	AC	2	$800.00	$1,600
Clean out sediment buildup in traps and ponds	EA	6	$60.00	$360
Repair damaged sections of filter fabric fencing	LF	25	$5.00	$125
Collect and dispose of sediments tracked offsite	LS	1	$3,200.00	$3,200
Subtotal erosion and sediment control BMP maintenance cost				$7,365
Contingencies (20%)				$1,473
Total ESC O&M cost (for 1 year only)				$8,840
Permanent stormwater quality control BMPs				
Mow infiltration and presettling basins	EA	2	$120.00	$240
Rake infiltration and presettling basins	EA	0.5	$780.00	$390
Clean out sediment buildup in presettling basin	EA	1	$300.00	$300
Periodically replace materials and equipment	LS	1	$250.00	$250
Clean catch basins and storm drains	EA	10	$200.00	$2,000
Parking lot sweeping	LS	1	$2,100.00	$2,100
			subtotal	*$1,180*
Subtotal permanent stormwater control annual O&M cost				$5,280
Contingencies (20%)				$1,056
Total annual O&M cost				$6,340